

# **THE PHYSICAL AND COGNITIVE BENEFITS OF CASUAL EXERGAME PLAY**

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By

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# ABSTRACT

Exercise can provide both physical and cognitive benefits to overall health, including long-term and short-term effects on wellness. In order to get these benefits, it is recommended that people perform at least 30 minutes of moderate-intensity exercise a day; however, many people do not get the recommended amount of exercise per day, which can result in health problems such as obesity and chronic disease. In this thesis, we propose a new genre of games called casual exergames, which we define as exergames that are designed to motivate people to exercise in small chunks of time multiple times throughout the day. Casual exergames have three advantages. First, games have been shown to have a strong motivation pull to play (i.e., people enjoy playing games), and casual games – those designed to be played in small chunks of time – have seen huge market success. Thus, we feel that applying casual game design to exergames will provide players with an enjoyable experience while performing physical activity. Second, research supports the approach of breaking exercise into small chunks, as the physical benefits of three moderate-intensity short bouts of physical activity (each lasting about 10 minutes) are similar to those of one continuous 30-minute bout. Thus, there should be physical benefits of casual exergame play. Third, short bouts of exercise have been shown to yield acute cognitive benefits. Thus a well-designed casual exergame should also produce measurable benefits to cognition. Following this approach, we designed and implemented a causal exergame called GrabApple, using the Microsoft Kinect sensor to detect body movement. Through the evaluation of GrabApple (carried out in three research studies), we show that a well-designed casual exergame can: 1) yield physical activity levels (similar to exercise on a treadmill) that meet the guidelines for moderate-intensity physical activity; 2) produce significant acute benefits to cognition over playing a sedentary version of the game; and 3) be integrated into a school setting with the potential of helping kids achieve physical activity thresholds, while also helping them to refocus throughout the day. In general, our game may encourage adults and school-aged children to get the recommended levels of exercise throughout the day and also obtain the acute cognitive benefits provided by physical activity.

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## CONTRIBUTIONS OF AUTHORS

The manuscripts found in this thesis were authored in collaboration with three other authors. The manuscripts in chapters 2 and 3 are co-authored by Dr. Regan Mandryk and the manuscript in chapter 4 is co-authored by Kathrin Gerling, Dr. Regan Mandryk and Dr. Kevin Stanley. The contribution for each author was similar, providing direction in the designing of experiments, sharing domain specific knowledge, and editing and verifying the final manuscripts.

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Figure 1. Screenshot of the GrabApple game.

## LIST OF ABBREVIATIONS

PAAS	Physical Activity Affect Scale
POMS	Profile of Mood Scale
AVG	Active video games
CVD	Colour vision deficiencies
PIP	PseudoIsochromatic Plate Ishihara Compatible
PAR-Q	Physical Activity Readiness Questionnaire
RPE	The Borg Rating of Perceived Exertion
%maxHR	Percentage of maximum heart rate
SAM	Self-assessment Manikin
TN	The total number of items processed (d2 test)
E	The total number of errors (d2 test)
E%	The percentage of errors (d2 test)
TN-E	The total number of items scanned minus error scores (d2 test)
CP	The number of correctly crossed out relevant items minus the errors of commission (d2 test)
PE	Physical Education
HBAM	Healthy Bodies Active Minds

# CHAPTER 1

## 1 INTRODUCTION

Getting enough exercise is critical for both adults and children, as exercise has a large impact on people's health and well-being [18]. Physical activity can reduce the risks of developing coronary heart disease, hypertension, high blood pressure, cancer, obesity, and diabetes [18]. Also, regular exercise has psychological and cognitive benefits such as decreasing depression, and stress [10] and improving mood [18]. Cognitive benefits include improving general memory, visual perception in adults [4] and academic performance in children [17].

Adults should do at least 30 minutes of moderate intensity exercise a day [18] to obtain the benefits of exercise. Children should get at least 60 minutes of moderate to vigorous exercise a day [1]; however, most adults [18] and nearly half of children do not perform their suggested amount [22].

One solution to have people get the recommended amount of exercise is to break down the long chunk of exercise into small multiple chunks (e.g., 10 minutes) throughout the day, so people may better manage this time commitment and have exercise fit into their busy schedules. For adults, research supports that breaking exercise into small chunks is a good approach because the physical benefits of three moderate-intensity short bouts of physical activity (each lasting about 10 minutes) are similar to one continuous 30-minute bout [2,9,15]. Similarly, children's physical activities can be carried out throughout the day in multiple short bouts lasting at least 15 minutes, including rest and recovery time [1].

The problem is that exercising in short bouts by doing activities like jumping jacks, stair climbing, or pushups is not much fun. Also, the motivational pull that comes along with playing sports is hard to reproduce in 10-minute chunks. In this thesis, we ask the question: Can technology be used to encourage people to exercise in short bursts throughout the day?

## 1.1 THE APPROACH OF CASUAL EXERGAMES

Previous work has revealed that applying physical activity as a mechanic of gameplay, can create a gaming experience that is both enjoyable and physically exertive [12]. This genre of game has been dubbed exergames [11] and has been extensively applied to support physical exertion in children [16], adults [20], and the elderly [8]. In order to make short bouts of exercise more enjoyable, we propose a new subgenre of exergame that we call casual exergames. Casual exergames can be defined as:

*Games that players can learn easily and access quickly, using simple rules and special game mechanics, to motivate them to exercise at a moderate intensity for short periods of play.*

We propose the genre of casual exergames for three reasons. First, people in general enjoy playing video games. Video games have a motivational pull that encourages both long-term and repeated play [13]. The genre of casual games – which are games that are designed to be played in small chunks of time and appeal to people of all ages – are particularly popular and comprise the largest proportion of players who game online [21]. Second, previous work showed as little as 10 minutes exercise can produce positive benefits to physical health [2,9,15]. Thus, creating exercise-based games that employ the principles of casual game design should yield physical benefits. Third, short bouts of exercise have been shown to yield acute cognitive benefits [19]. Thus, a well-designed casual exergame should also produce measurable acute benefits to cognition. Therefore, by applying casual game design to the design of exergames, we hope to provide players with the physical benefits and acute cognitive improvements associated with exercise, but in an experience that is motivating and enjoyable.

Based on our definition of casual exergames, we designed and implemented a casual exergame, called GrabApple. We used the Microsoft Kinect sensor to detect players' body movements and used the player's own body weight as resistance to generate physical exertion. We applied the principles of casual game design to ensure that the play experience would remain fun in a short

period of play. We also applied game mechanics that rewarded players for greater exertion, ensuring that the experience was exertive.

We conducted three research studies to evaluate our game. All the studies were approved by ethics offices at the University of Saskatchewan. In the first two studies, we examined the physical and cognitive benefits after a short bout of a casual exergame play. It is important for casual exergames to be engaging to people and also provide physical and cognitive benefits. There have been mixed results of studies that investigate the efficacy of exercise produced by exergame play. Some research suggests that the exertion produced by commercial exergames is not sufficient to meet current physical activity guidelines [14]. Through the first study, we show that short bouts of casual exergame play could yield enough exertion to meet the current physical fitness guidelines while providing players a fun experience. In the second study, we investigated the physical exertion of casual exergame play as compared to traditional exercise on a treadmill. We also investigated the cognitive benefits that resulted from play. Because previous research suggests that exergames may not meet current guidelines for exertion, it is possible that cognitive benefits of short bouts of exercise may not result from casual exergame play. Also, it is possible that the presence of the cognitive components of game play may interfere with the cognitive benefits that have previously been shown to result from traditional exercise. In this study, we showed that as little as 10 minutes of casual exergame play could produce acute cognitive benefits (concentration) compared with a sedentary version of the same casual game. From the two studies, we know that casual exergames designed to be played in short periods of time have the potential to help people reenergize and refocus during their down time. In the third study, we explored whether casual exergames are feasible in a classroom-like setting to encourage exercise among school-aged children. As children grew older, their attitudes towards exercise may change and some children no longer consider physical activity to be fun [3]. Also, children are becoming more sedentary, such as not attending Physical Education classes regularly [18]. Therefore, deploying casual exergames in classrooms may be a good approach to motivate children to perform physical activities throughout the day, such as recess time and class breaks. In our third study, we demonstrated casual exergames yield effects similar to those shown in lab studies and are considered enjoyable by students. Also, based on the investigation of students' and teachers'

attitudes towards exercise and exergames at school, we had general discussion on casual exergamedeployment at school for future work.

Overall, casual exergames may encourage adults and school-aged children to get the recommended levels of exercise throughout the day and also obtain the acute cognitive benefits provided by physical activity.

## **1.2 OVERVIEW**

This thesis is a combination of three manuscripts. Chapter 2 and chapter 3 have been published as peer-reviewed conference papers and chapter 4 is under review as an invited submission to a journal.

In chapter 2, we presented three contributions. First, we combined the design of casual games with the design of exergames and came up with a new genre of casual exergames. Second, based on the definition, we designed and implemented a casual exergame called GrabApple. Third, through the user study, we showed participants' heart rate was elevated to an average of 72% of maximum heart rate, and that players burned an average of 91.8 Calories for 10 minutes of play, which produced sufficient physical activity to meet the current fitness guidelines. These findings are encouraging as they demonstrated that a casual exergame has the potential to help users gain the health benefits of exercise in a fun way; however, what remained unclear was whether playing casual exergames resulted in acute improvements in cognition, and whether the benefits produced were similar or better compared with traditional exercise activities and a sedentary casual game.

In Chapter 3, we explored the questions that arose from our results chapter 2 and we had four main contributions. First, we found that 10 minutes of casual exergame play produced similar exertion levels to running on a treadmill and significantly higher exertion levels than playing a sedentary casual game. Second, we found that 10 minutes of casual exergame play improved performance on three cognitive tests that measure concentration compared to a sedentary casual

game. Third, we found that players experienced greater fun playing a casual exergame than exercising on a treadmill exercise. Fourth, we found improved affective states after casual exergame play. These findings suggest that short periods of casual exergame play can result in both physical and cognitive improvements.

In Chapter 4, we investigated the feasibility of a casual exergame deployment in classroom settings and we had two contributions. First, we showed that casual exergames can be deployed in a classroom setting, yielding effects similar to those shown in our lab studies. Second, we investigated and reported students' and teachers' attitudes towards exercise and exergames in a school setting and provide an overview of their opinions as a basis for future work.

### **1.3 THE MANUSCRIPTS**

As previously mentioned, three related manuscripts make up this thesis. The manuscripts are outlined below. The first two manuscripts have been published and the third manuscript is under review as an invited article to a “best of conference” special issue of a journal.

#### **1.3.1 Manuscripts Included in This Thesis**

Chapter 2 is built upon the following reference:

[7] Gao, Y., and Mandryk, R.L. (2011). GrabApple: The Design of a Casual Exergame. In *the proceedings of The International Conference on Entertainment Computing (ICEC '11)*, Vancouver, BC, Canada. 35-46. Best Paper Nomination. The international conference on entertainment computing (ICEC) is an international conference combined research and practice, such as art and design with engineering and computer science. Our paper was nominated for the Best Paper Award (4 nominated papers – 1 winner). In 2011, this conference was held in Vancouver Canada. The acceptance rate for papers submitted to the conference was 31%.

Chapter 3 is built upon the following reference:



[6] Gao, Y., and Mandryk, R.L. (2012). The Acute Cognitive Benefits of Casual Exergame Play. In *the proceedings of the 30th international ACM conference on Human factors in computing systems (ACM CHI 2012)*, Austin, Texas, USA. 1863-1872.

The ACM SIGCHI Conference on Human Factors in Computing Systems (CHI) is an international conference on human-computer interaction and it is the top conference in the general field of human-computer interaction. There were 1577 papers and notes submitted to the conference and 287 were accepted for an acceptance rate of 23%

Chapter 4 is built upon the following submitted paper:

[5] Gao, Y., Gerling, K., Mandryk, R.L., and Stanley, K.G. (under review). Engaging Pre-adolescents in Physical Activity with Casual Exergames. Submitted to *Entertainment Computing*. 24 pages.

*Entertainment Computing* (Elsevier) publishes original, peer-reviewed research articles in all aspects of digital entertainment, new media, entertainment computing, gaming, robotics, and toys. This is a special invited issue of extended papers from the ICEC 2011 conference to comprise a “Best Of ICEC” issue. Invited papers must include 30% new material and 30% rewritten material. The papers will be peer reviewed and the process is competitive. Although a number of papers were invited, only six papers will be accepted for inclusion.

Each paper is retained in the original formatting of the venue in which it was accepted. As such, references are included at the end of each chapter, rather than at the end of the entire document.

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## CHAPTER 2

### 2 GRABAPPLE:THE DESIGN OF A CASUAL EXERGAME

In this chapter we begin with the general problem that many people do not get the recommended 30 minutes of exercise per day. Based on the strategy of breaking down the 30 minutes of exercise into smaller chunks (e.g., 10 minutes of activity, 3 times per day), we came up with the idea of casual exergames, which can motivate people to do multiple 10-minute bouts of exercise in a fun way throughout the day.

Next, we cover the related literature about casual games and exergames. We outline the generally agreed upon definition by which a game can be considered as a causal game. We also address the efficacy of both commercial and research-based exergames. Because we created the concept of a casual exergame, there was no previous framework to understand how to apply the principles of casual game design to exergames. We provide our definition of casual exergames, which are games that players can learn easily and access quickly, using simple rules and special game mechanics, to motivate them to exercise at a moderate intensity for short periods of play.

Following the related literature, we designed and implemented a casual exergame called GrabApple, and we discussed the casual interaction design of the game and how to get moderate-intensity exercise level by using game mechanics.

Finally we presented our preliminary study on the enjoyment and the exercise intensity during a 10-minute casual exergame play session compared with the same mouse-based casual game. The results show that users enjoyed playing the casual exergame, and if played three times per day, our casual exergame produced sufficient physical activity to meet current fitness guidelines. This chapter is fundamental to the thesis, as the first step of our work is to ensure that a casual exergame is both fun to play as well and produces sufficient exertion levels.

# GrabApple: The Design of a Casual Exergame

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**Abstract.** Many people do not get the recommended 30 minutes of exercise per day, which can result in health problems such as obesity, muscle atrophy and chronic disease. Based on the principles of casual games and exergames, we propose and define casual exergames for motivating people to exercise in multiple small chunks of time throughout the day. We designed, implemented, and tested a casual exergame called GrabApple. Our preliminary results show that users enjoyed playing the casual exergame and that in just 10 minutes of play, their heart rate was elevated to an average of 72% of maximum heart rate, and that they burned an average of 91.8 Calories. If played three times per day, our casual exergame produced sufficient physical activity to meet current fitness guidelines. We discuss the potential health benefits of casual exergames.

**Keywords:** Exercise, casual game, exergame, exercise efficacy.

## 1 Introduction

People should do at least 30 minutes of moderate-intensity exercise a day; however, most people do not perform this suggested amount of daily exercise despite the benefits [1]. First, regular exercise can reduce the risks of developing coronary heart disease, hypertension, high blood pressure, colon cancer, obesity, and diabetes [1]. Second, physical activity can relieve symptoms of depression and anxiety, and improve mood [1]. Third, aerobic exercise has been linked to cognitive benefits, improving many aspects of cognition and brain function [2]. Finally, a healthy society produces less strain on an overburdened health care system.

One strategy to encourage people to get their recommended amount of daily activity is to break the 30 minutes of exercise into smaller chunks so it is more manageable. People might then be able to better manage this time commitment, and there would also be a lower overhead to exercising, including reducing the need to change into exercise clothes or shower after exercising. Research supports that breaking exercise into small chunks is a good approach because the physical benefits of three moderate-intensity short bouts of physical activity (lasting about 10 minutes) are similar to one continuous 30-minute bout [3, 4]. Still, given a 10-minute break in their day, many people do not choose to use this time to exercise because typical short bursts of activity, such as climbing stairs or jogging for 10 minutes are not very enjoyable. Many people say they do not exercise so they can do other activities, such as watching television (47% of respondents selected this), sleeping in (43%), doing household chores (59%) or working (43%) [5].

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One approach to making exercise more fun is through the use of exergames, which are games that use exercise as part of the activity required to play a video game [6, 7]. Exergames have been shown to be more fun to play than a corresponding level of standard exercise [7]. Although exergames can promote physical activity, these games are often tedious to set up, use specialized hardware, and need a committed chunk of time to play. To motivate people to do 10-minute bouts of exercise in a fun way, we take the novel approach of applying the principles of casual games—which have been described as games that are “fun, quick to access, easy to learn and require no previous special video game skills, expertise or regular time commitment to play” ([8], p.3)—to exergames [7], creating the new genre of casual exergames. We define casual exergames as *games that players can learn easily and access quickly, using simple rules and special game mechanics, to motivate them to exercise at a moderate intensity for short periods of play*. The advantages of casual exergames are two-fold. First, casual games appeal to people of all ages, genders and nationalities [8], are fun, and are easy to start and stop playing. Second, exergames have game mechanics promoting exercise so it makes exercise seem less difficult and more enjoyable [7]. Therefore, casual exergames should motivate physical play in small manageable chunks of time, and help people to exercise for the recommended 30 minutes per day.

We designed and implemented a casual exergame based on the principles of casual games and exergames. To make the game simple to play we use the player’s body as the game controller, where movement is sensed through the use of inexpensive and accessible hardware (Microsoft Kinect sensor). Through a four-month development process, we iteratively playtested our game, generating a short, fun, and easy-to-learn play experience that caused players to elevate their heart rate and burn Calories.

We then conducted a preliminary study to investigate how much fun our game is and how much exercise it produces in players. We compared our casual exergame to a mouse-based version of the game using eight study participants. Initial results showed that the casual exergame is fun to play and can elevate players’ heart rates to target levels for moderate-intensity aerobic exercise. We discuss the potential health benefits of casual exergames and present future research opportunities in this space.

## 2 Defining Casual Exergames

### 2.1 Casual Games

In 2006, the casual games industry was a \$2.25 billion/year industry and was growing by 20%/year [8]. This was prior to the smartphone and tablet revolution, which has catapulted casual games into an entirely new level of popularity. There are many definitions for casual games and the community has yet to converge on a final definition [9]. The Casual Games SIG of the International Game Developer’s Association (IGDA) defines casual games as “games with a low barrier to entry that can be enjoyed in short increments” ([10], p.9). The casual games community has generally agreed on the following criteria for a game to be considered casual:

**Easy to learn.** Casual games should have limited instructions, provide rules that are easy to learn, and guide players with a clear and consistent user interface [10].

**Simple controls.** Casual games should take advantage of assumed knowledge, such as drag, drop and click [10].

**Play in a relatively short play period.** Casual games should be able to be enjoyed in a series of short time increments, though sometimes people play one level after another for many hours [8]. Most casual games' play intervals are between 5 and 15 minutes to complete a level [8].

**Reduced complexity and non-punishing game play.** Casual games allow depth and complexity to emerge from the player's basic actions instead of making the player master a large and complex set of actions [10].

**Family friendly.** The IGDA Casual Games SIG deems that casual games should not contain objectionable content, such as overt violence, or sexuality [10]. The CGA agrees that casual games should appeal to people of all ages, genders and nationalities [8]. In recent years, casual games have been developed (e.g., games rated 17+ for Apple's iPad) that do not adhere to this criterion.

## 2.2 Exergames

Exergames can motivate players to be more physically active by combining games and exercise together. Some commercial games can be considered exergames. For example, in Dance-Dance Revolution, players step on colored sections on a platform to musical and visual cues [11]. Wii Fit works directly with the Wii console to bring players a fun and exciting way to experience fitness [12].

Researchers have designed and tested a variety of exergames. Some games use custom sensors such as in Ping Pong Plus [13], Breakout for Two [6] and Kick-Ass Kung Fu [14]. Others have integrated standard exercise equipment, such as the stationary bikes used in Heart Burn [15] and Life is a Village [16]. Exergames have also been developed that do not prescribe the type of exercise, but are based on the player's heart rate, such as Triple Beat [17] and Nenonen et al.'s biathlon game [18].

Because our game is intended to be a casual game, the overhead to play needs to be minimal and we cannot use expensive hardware, such as resistance bikes or custom sensor floors. We chose to use the movement of the body as input to the game, requiring no game controller or exercise equipment.

**Efficacy of Exergames.** The goal of exergames is to create play experiences that are both fun and that elevate heart rate. In general, researchers have shown that their exergames are fun to play, but do they have the same benefits as regular exercise? Research shows that many exergames can be utilized as part of an overall aerobic exercise program because in a 30-minute exercise session, a player's heart rate and caloric expenditure are both within the American College of Sports Medicine recommendation for daily physical activity [19]. However, in another study that investigated the relative efficacy of Wii games and their real life sports counterparts, it was shown that the energy that players used to play active Wii Sports games was not of high enough intensity to reach the recommended daily amount of exercise in

children [20]. It is important for exergame researchers to demonstrate the efficacy of the exercise generated by their game to ensure that the players of these games are getting the health benefits of exercise. An alternative viewpoint is that playing exergames (as opposed to traditional games) means that players are at least unable to simultaneously play and work their way through an unhealthy snack such as a bag of potato chips. Although perhaps not a direct benefit, replacing traditional games with exergames will at the very least prevent this type of unhealthy behavior.

### 2.3 Casual Exergames

Because we are proposing a new genre of game, there is not a previous framework to understand the casual and exergame aspects of casual exergames. We propose that casual exergames are games that require exertion to play and adhere to the criteria of casual game design. More specifically we define casual games as *games that players can learn easily and access quickly, using simple rules and special game mechanics, to motivate them to exercise at a moderate intensity for short periods of play*.

Some people argue that exergames developed for recent commercial gaming platforms, such as Wii Sports, can be considered as casual games [8, 10] because they are easy to learn, are family friendly and use simple controls. However, many commercial exergames do not provide enough exercise intensity to be considered a casual exergame by our standards. For example, previous work shows that the energy used playing active Wii Sports games is not intense enough to reach the recommended daily amount of exercise for children [20]. In addition, these commercial games do not necessarily meet the criteria for casual games defined previously; i.e. casual games must be able to be played in a relatively short play period. If casual games are to be played in short play periods, they should also be quickly accessible games with little-to-no setup time [10]. If setting up a console game requires even 5 minutes to boot the system, navigate the menus, and calibrate the controllers, then it is not in line with the duration of play expected of a casual game. Finally, the accessibility of gaming consoles, which are generally kept in domestic environments, limits their use as systems on which to play exergames during breaks in the work day.

## 3 GrabApple: A Casual Exergame

We designed GrabApple—a casual exergame that uses the player’s body as the game controller and the player’s own body weight as resistance to elevate heart rate. In this section, we describe the design and implementation of GrabApple and show how it conforms to the principles of casual game design and efficacious exergame design.

### 3.1 Game Concept

In GrabApple (Figure 1), the goal is for players to try to pick up falling red and green apples and avoid touching the falling bombs. Apples and bombs are picked and



touched using a virtual hand whose position on the screen is controlled through the movement of the player's body. Each apple picked adds one point to the total player score, while each bomb touched subtracts five points.



**Fig. 1.** GrabApple. Players move the hand to grab falling apples while avoiding falling bombs

**Designing for Casual Interaction.** We designed the game to conform to the principles of casual game design in the following ways:

- 1) *Easy to learn.* The concept of GrabApple is easy to learn – a player should touch the apples and avoid the bombs. There are only two additional mechanics: players can only hold five apples at a time and thus need to empty the virtual hand into a collection bag; and there is a mushroom bonus that appears and players have to press a key on the keyboard to get extra points. Also, we clearly provide feedback to players on their performance through floating scores and an energy bar that displays total points (Figure 1).
- 2) *Simple controls.* GrabApple uses the player's body as the game controller. The virtual hand is mapped to the player's movements so players jump, duck and move to control the virtual hand movement.
- 3) *Play in a relatively short play period.* GrabApple takes an average of three minutes to complete a game level. The setup time is also in line with short play periods. After plugging the Microsoft Kinect sensor into the computer's USB port, the player launches the application in a similar manner to most casual games. With the short setup time and the use of standard computers, players can quickly access and play our casual exergame.

- 4) *Reduced complexity and non-punishing game play.* The game mechanics and controls of GrabApple are simple. In addition, it is difficult to lose the game, but players are rewarded after completing a level with an unlocked higher level and can compete for the high score.
- 5) *Family friendly.* GrabApple has no objectionable, violent, or sexual content.

**Designing for Efficacious Exercise.** We motivate people to get the recommended aerobic exercise intensity level through the game design and game mechanics.

- 1) *We encourage players to move around.* We give score multipliers for picking consecutive apple of the same color and give a penalty for touching any bombs. This encourages the players to move the virtual hand around the screen instead of standing and waiting for the apples to fall.
- 2) *We elevate players' heart rates by using their own weight as resistance.* The virtual hand on the screen can only hold five apples. Players have to empty the virtual hand by putting it into the collection bag on the right side of the screen. They can only reach this bag by running to the side and jumping, thus using their body as resistance and increasing their heart rate. Also, in order to pick up the maximum number of apples, players need to jump up and bend down.
- 3) *We elevate players' heart rates by adding extra exercise.* Once in a while, a mushroom appears on the screen and players can get a five-point bonus by picking up the mushroom. In order to receive the bonus points, players have to run to the keyboard and press any key. Players have to hurry, as the mushroom is only available for two seconds, so they need to reach the keyboard as fast as they can. Because players stand approximately 1.5 meters from the keyboard when playing the game, quickly running to the keyboard increases overall activity.
- 4) *We raise exercise intensity by increasing game difficulty through game levels.* In higher game levels, we increase the speed and the number of falling apples and bombs. These game levels become accessible when players get sufficient points as shown by the energy bar on the left of Figure 1.

We designed our game for casual play and for exercise, but also designed the game to be fun to play through the use of reward animations and player achievements [21].

### 3.2 Game Implementation

We implemented two versions of our game: the exergame and the mouse version. Both games were programmed in Processing. For the casual exergame, we use the Microsoft Kinect sensor to detect users' body movements. The Kinect is essentially comprised of one camera that detects x and y position and another infrared receiver camera that detects depth through the dispersion of dots displayed via an infrared transmitter. In our game, we can track the player's body movement by the average location of a given number of points that meet a specific depth threshold. We use Daniel Shiffman's Kinect library for Processing [22]. For the mouse-based version, we use the mouse cursor location to control the position of the hand on the screen and players left clicked the mouse to empty the hand into the collection bag.



**Fig. 2.** Playing the Kinect (left) and mouse version (right)

## 4 Preliminary Study

We investigated the enjoyment of our game and the intensity of exercise during play.

### 4.1 Participants

We recruited 8 university students (7 male), aged 22 to 44 (mean of 29). Six of the participants played video games at least weekly; the other two played only a few times a year. Our players reported that they play different types of video games, including role-playing games, first-person shooters and puzzle games. None of our participants play games using the Kinect on a regular basis.

When asked about their daily exercise, only 3 out of 8 participants got 30 minutes of sustained physical activity per day. Four participants exercised for 15-30 minutes per day, while one exercised for 0-15 minutes per day. Most players (five) said that they do not have time to complete the daily-recommended amount of exercise, and three said that their lack of exercise was due to laziness. When asked if they take regular breaks during the workday, six of our players said that they take a break every hour or two. The other two reported that they seldom took breaks.

### 4.2 Apparatus

The game was played on Mac OS X 10.6.6 with a 20-inch monitor. A low resolution (800×600) was used as players stood about 1.5 meters from the display to play the casual exergame. During the play of the casual exergame, players wore a Garmin Forerunner 110 heart rate monitor with a strap around the chest so we could log their heart activity and the Calories burned.

### 4.3 Procedure

A within-subjects design was used where participants played both the casual exergame and the mouse-based version. To reduce crossover effects between conditions, players visited the laboratory on two consecutive days to participate. To reduce differences between conditions, we had participants play at approximately the same time each day and asked them to try to keep their patterns the same prior to each

experimental session in terms of the amount and time of food and caffeine consumption, and the amount of sleep. To reduce order effects, half of the participants played the casual exergame on the first day, while the other half played the mouse-based version first.

Participants began by filling out an informed consent form and learning the rules and procedures of the game through an initial training session. Then participants played the game for 10 minutes. After playing the game, participants rated their exertion level according to the Borg Rating of Perceived Exertion Scale, where people subjectively rate how hard they feel they are working on a 15-point scale ranging from 6 (no exertion) to 20 (maximal exertion) [23].

After completing the second experimental session, participants filled out a questionnaire asking about their demographic information and for a comparison of the two game versions.

## 5 Results

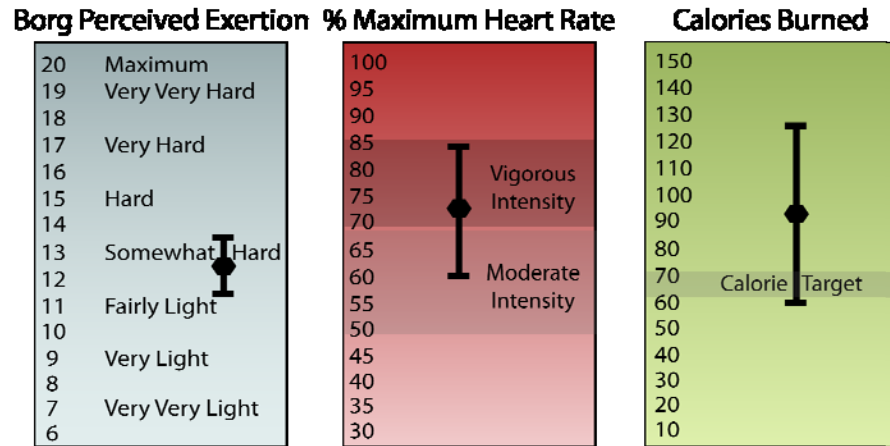
We first present the results for the efficacy of exercise, followed by the results related to the enjoyment of the game.

### 5.1 Efficacy of Exercise of GrabApple

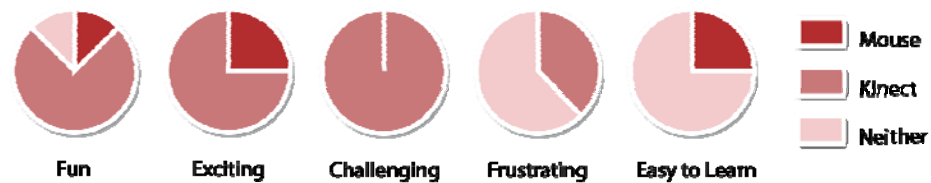
The American College of Sports Medicine recommendations for moderate-intensity exercise is 64–76% of maximum heart rate (220-age) [24]. After our participants played the casual exergame for 10 minutes, their average heart rate was 72% (SD=12%) of their maximum heart rate, which is in the range of moderate-intensity exercise. The average Calories burned in those 10 minutes was 91.8 (SD=31.86). If we assume that participants play our game for three 10-minute bursts per day, the average Calorie expenditure will be 275, which exceeds the recommended Calories per day that adults should burn through aerobic exercise (200 Calories)[25]. The average Borg Rating of Perceived Exertion after playing the casual exergames was 12.38 (SD=0.85), which is within the recommended intensity for improving aerobic capacity of 12-13 (somewhat hard) to 15-16 (hard) [23]. The exercise efficacy of GrabApple as indicated by our measures is shown in Figure 3.

### 5.2 Exergame vs. Mouse-Based Game

We asked participants to rate five aspects of the game (fun, exciting, challenging, frustrating, and easy to learn) on a 5-point Likert scale (1=strongly disagree, 5=strongly agree) after playing each version. Given the non-parametric nature of our ratings data, we transformed these ratings into ranks – for each question, participants chose the mouse version, the Kinect version, or neither. Figure 4 shows the rankings. A chi-squared test for each aspect reveals that more participants thought that the Kinect version was more fun ( $\chi^2=6.3$ ,  $p=.044$ ), more exciting ( $\chi^2=7.0$ ,  $p=.030$ ), and more challenging ( $\chi^2=16$ ,  $p\approx.000$ ). They were equally easy to learn as evidenced by a majority of participants choosing neither the mouse nor the Kinect version ( $\chi^2=7.0$ ,  $p=.030$ ). There was no difference in the choice of game for frustration ( $\chi^2=4.75$ ,  $p=.093$ ).



**Fig. 3.** Our three measures of exercise efficacy. Dots represent the mean of that measurement over all players and error bars represent one standard deviation in player measurements. The average perceived exertion is somewhat hard, the average heart rate is within recommended targets for aerobic activity, and the number of Calories burned exceeds the recommended Calories that adults should burn through physical activity three times daily.



**Fig. 4.** Participant rankings for the two versions of the game. The size of the pie wedge for the mouse and Kinect version shows the number of participants who ranked that condition higher. The 'neither' wedge shows the number of participants who ranked both versions equally.

We asked whether participants would consider playing the casual exergame when they had a ten-minute break during their day. Five participants agreed or strongly agreed, with one participant answering each of neutral, disagree or strongly disagree. The participants who disagreed were also two of the bottom three participants in terms of exercise intensity as measured by both target heart rate and Calories burned. It could be that these players were not sufficiently motivated by the game to try hard and would not choose to play it again. It could also be that these players were quite fit and the game did not promote enough activity for them (in which case they don't need a casual exergame to get the recommended daily activity levels). For one of the players, this was the case as s/he already gets over 30 minutes of exercise every day.

## 6 Discussion

Our results showed that GrabApple is fun and that most of our participants would consider playing the casual exergame during breaks in their day. Our results also

showed that the level of exercise produced by our casual exergame is sufficient to provide health benefits when played a few times per day in 10-minute increments. After playing the Kinect version of GrabApple for ten minutes, participants' average heart rate, Calorie expenditure and Borg exertion rate were all within the recommended exercise intensity [23-25].

In summary, our casual exergame was fun to play and produced a level of exercise consistent with targets for moderate-intensity aerobic activity.

## 6.1 Future Work

Although our initial results are very encouraging, there are three main research directions that we plan to pursue to establish casual exergames as a method for improving health. First, we need to design and implement a suite of casual exergames. To encourage play for the recommended 30 minutes of activity per day, we need to provide players with a selection of games so that repeating the play of a single game during each exercise break does not bore them. As part of this process, we will use the feedback provided by our participants to adjust the gameplay of GrabApple. For example, one player recommended giving score multipliers for consecutive apples grabbed using duck then jump movements. These changes could increase the amount of exercise achieved during play. Second, we need to establish that people are sufficiently motivated by the casual exergames to play them when not participating in an experiment. To find out whether people will partake in short bursts of physical activity by playing casual exergames, we will supply our suite of casual exergames to participants for a longer-term study. Through a combination of data logging and exit interviews, we can establish how well our games motivate people to exercise in small bursts throughout their day. Third, we need to conduct larger studies to establish the health benefits of casual exergames. We plan to consider both physical health and cognitive health as physical activity can relieve symptoms of depression and anxiety [1], and improve mood [1] and cognitive function [2]. Finally, as new forms of activity sensors become available on personal computers, laptops and smartphones, we will consider how to develop casual games for emerging sensing hardware to continue to improve the accessibility of casual games for players.

## 7 Conclusion

To encourage increased physical activity through short bouts of fun activity, we applied the principles of casual game design to exergames in our design and implementation of GrabApple – a casual exergame. Initial tests of GrabApple are encouraging. First most of our participants enjoyed playing the casual exergame and would consider playing the game during breaks in their day. Second, participants' heart rates were elevated to aerobic levels and sufficient Calories were burned during game play. In general, we are encouraged by our preliminary investigation and plan to continue this line of research with further development and formal studies of casual exergames. Casual exergames are an interesting new genre of games that can add physical activity into people's daily routines in an enjoyable way.

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## CHAPTER 3

### 3 THE ACUTE COGNITIVE BENEFITS OF A CASUAL EXERGAME PLAY

#### 3.1 OVERVIEW OF CHAPTER 3

In chapter 2, we applied the principle of casual game design to the design of exergames and designed an engaging casual exergame called GrabApple. Through our preliminary study we know that a casual exergame has the potential to help people do multiple 10-minute bouts of exercise in a fun way throughout the day and that the level of exertion produced is sufficient to meet current guidelines. Because we knew that we were also interested in potential cognitive benefits, when we conducted our preliminary study in chapter 2, we also investigated whether there are acute cognitive benefits, such as temporary improvements in concentration and affective improvements after playing the casual exergame. Many researchers had found that as few as ten minutes of exercise can result in the temporary acute cognitive improvements. We wondered whether these results would also apply to casual exergame play or whether the presence of the cognitive components of game play may interfere with the cognitive benefits that have previously been shown to result from traditional exercise.

While conducting the preliminary study presented in chapter 2, we also had four participants complete the a version of the WRAT4 reading test and four complete a version of the WRAT4 math test after playing in each game condition (mouse game and exergame). The versions (Blue and Green) were balanced across the game conditions. Although we had only a few participants in each condition, a paired one-tailed t-test (because we expected differences) revealed that there may be cognitive benefits of our casual exergame as measured by the math test ( $t_3=2.5$ ,  $p=.046$ ). The average reading score did not differ after playing the two game versions ( $t_3\approx 0.0$ ,  $p=0.5$ ). With only 4 participants in each condition, we feel that these results have to be interpreted with caution; however, the consistent (albeit small) differences in the math scores were encouraging

and we decided to further explore the cognitive benefits of playing casual exergames in a formal study.

To further explore the possibility of cognitive benefits, and also to compare our game to traditional exercise, we conducted two studies to compare playing ten minutes of our casual exergame to a sedentary version of the game or exercise on a treadmill. To measure cognitive performance, we used three different standard cognitive tests that measured attention and concentration. We did not continue to use WRAT4 reading test, as the performance was quite variable for participants who did not speak English as their first language. Also, the WRAT4 reading test generally demonstrated participants' reading comprehension rather than their acute concentration. When we chose the standard cognitive tests, there were in general two requirements. First, the cognitive tests needed to be completed in a relatively short time, as we do not know how long potential acute cognitive benefits would last. Second, the cognitive tests needed to have little or no restrictions and be easy to use. In the first study, we used the Stroop Color and Word test; however, we again noticed inconsistencies in the performance of participants who did not speak English as a first language. As such, we chose to use the D2 test of attention and WRAT-4 math computation test in the second study.

Our results showed that the casual exergame produced similar exertion levels to treadmill exercise, but was perceived as being more fun. Most importantly, we observed improved cognitive performance after casual exergame play over the sedentary version but not treadmill exercise. This cognitive performance results are in line with previous research on the acute cognitive benefits of traditional exercise. Also, significant improvements were found in participants' affective states after playing the casual exergame.

After demonstrating the physical activity levels and cognitive benefits that result from only 10 minutes of casual exergame play, at the end of this chapter, we discussed how these findings could be applied in our daily lives to help people gain the potential benefits. Playing casual exergames is perceived as an enjoyable activity that requires little overhead to set up, and it can be deployed at schools to help children refocus at their critical times during the day. In chapter 4, we further explored the possibilities for casual exergames deployment in school.

# The Acute Cognitive Benefits of Casual Exergame Play

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## ABSTRACT

Acute cognitive benefits, such as temporary improvements in concentration, can result from as few as ten minutes of exercise; however, most people do not take exercise breaks throughout the day. To motivate people to receive the cognitive benefits of exercising in short bursts multiple times per day, we designed an engaging casual exergame. To determine whether there are cognitive benefits after playing our game, we conducted two studies to compare playing ten minutes of our casual exergame to a sedentary version of the game or exercise on a treadmill. We found acute cognitive benefits of the casual exergame over the sedentary version (but not treadmill exercise), demonstrated by significantly improved performance on two cognitive tests that require focus and concentration. Significant improvements were also found in participants' affective states after playing the casual exergame. Finally, our casual exergame produces similar exertion levels to treadmill exercise, but is perceived as more fun.

## Author Keywords

Exercise; casual game; exergame; cognitive benefits; affect.

## ACM Classification Keywords

H.5.2 [Information Interfaces And Presentation]: User Interfaces - Input devices and strategies.

## INTRODUCTION

Regular exercise has many physical and cognitive benefits. Physical benefits, such as reducing the risks of coronary heart disease or diabetes [43] are well known. Cognitive benefits of exercise are not as well known, but are as important as the physical benefits. Regular exercise leads to the relief of symptoms of depression and anxiety [43], mood improvements [43], and improvements in memory, visual perception, and processing speed [8].

In addition to the general cognitive benefits produced by regular exercise, research has also shown acute (i.e., short and temporary) cognitive benefits in working memory [27], concentration [19,33], and mood [5,12,19]. Some studies suggest that only 10 minutes of exercise can produce acute

effects on cognition [40]. If performed three times daily, people doing 10-minute bursts of physical activity could not only get the physical benefits of a sustained 30-minute block of exercise [6,13,32], but could also improve their focus, concentration, and mood throughout the day.

To make it convenient for people to exercise for only ten minutes multiple times a day, exercise activities must be accessible and require little time to set up, such as doing jumping jacks, or running up and down stairs; however, these short-duration activities are not much fun. *Casual exergames* are computer games that players can learn easily and access quickly, using simple rules and special game mechanics, to motivate them to exercise at a moderate intensity for short periods of play [42]. Casual exergames are engaging, and have been shown to elevate players' heart rates to target levels for moderate-intensity aerobic exercise [42]. Because playing casual exergames is an enjoyable activity that requires little overhead to set up, people might be willing to play casual exergames multiple times per day, receiving the benefits of bursts of moderate-intensity exercise throughout the day [43].

What remains unclear is whether playing casual exergames can result in acute improvements in cognition and mood and whether the benefits produced are as pronounced as those produced by performing traditional exercise activities, such as running. Investigations into the efficacy of exercise produced by exergame play have seen mixed results. Some research suggests that the exertion produced by commercial exergames is not sufficient for physical activity guidelines [10], suggesting that cognitive benefits may not result.

To investigate the potential cognitive benefits of casual exergames, we conducted two studies examining the effects of casual exergame play on cognition and affective state. We used a game that we previously developed, which was shown to produce moderate-intensity levels of physical activity when played using a Microsoft Kinect [42]. We compared our casual exergame to a sedentary version of the game played with a mouse, and to traditional exercise (running on a treadmill). In a second study, we further explored the cognitive and affective benefits of our casual exergame compared to the mouse-based version.

Study 1 showed evidence of cognitive benefits of the Kinect and exercise conditions over the mouse condition, as measured by a Stroop test [20]. In Study 2, participants performed significantly better on the d2 test of attention [4] and on a standard math test [39] after playing the casual

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exergame version as compared to the sedentary mouse-based version. In addition, significant improvements in participants' affective states were found in both studies after playing the casual exergame. Finally, our casual exergame produces similar physical benefits to exercise on a treadmill, but is perceived as more fun.

Our work is the first to show that playing a casual computer exergame for ten minutes at a time can produce cognitive benefits. Because these games are engaging, require little overhead to set up or time commitment to play, deployment in schools, workplaces, and homes for repeated play throughout the day might result in improved physical health of players, but also the cognitive health of players.

## RELATED WORK

We cover literature on the benefits of exercise, exergames, the efficacy of exercise in exergames, and casual games.

### Benefits of Exercise (Physical, Cognitive and Mood)

To obtain the benefits of exercise, people should do at least 30 minutes of moderate-intensity exercise a day; however, most people do not perform this suggested amount [43], citing issues such as a lack of time, not making exercise a priority, and being too lazy. Physical benefits of exercise are well known and include reducing the risks of developing coronary heart disease, hypertension, high blood pressure, cancer, obesity, and diabetes [43]. Regular exercise also has psychological and cognitive benefits. It has been shown that fitness through physical activity can enhance psychological well-being, such as decreasing depression, stress, cynical distrust and anger [14], and improving mood [43]. Also, aerobic fitness has been linked to cognitive benefits, such as fluid intelligence, general memory, visual perception, retrieval ability and processing speed (see [8] for a meta analysis).

### Acute Benefits of Short Bouts of Exercise

In addition to the general relationship between aerobic fitness and cognitive function, researchers have also shown acute (i.e., short and temporary) cognitive benefits after single bouts of exercise. In these cases, performance on a cognitive task has improved directly following a short bout of exercise. Acute improvements in cognitive function have been shown using a number of cognitive tasks, including the Working Memory Task [27], the Rey Auditory-Verbal Learning Test [7], which measures recall, and the Stroop test [19,33,40], which measures concentration. In addition to acute cognitive benefits, short bouts of exercise have been shown to improve mood using the Physical Activity Affect Scale (PAAS) [5], the Nowlis Mood Scale [19] and Profile of Mood Scale (POMS) [12,19].

Although most studies examining the acute benefits of exercise use longer bouts of activity, both cognitive benefits and mood improvements can be found after performing as few as 10 minutes of moderate-intensity exercise [12,40]. Performing exercise in small chunks also does not reduce

the physical benefits as research shows that the physical benefits of three moderate-intensity 10-minute bout are similar to one continuous 30-minute bout [6,13,32].

### Benefits of Video Games (Cognitive and Mood)

Research has shown general benefits that playing video games has on cognition and mood. Playing video games has been shown to increase attentional capacity [11] and the ability to mentally manipulate multiple spatially-represented objects [25]. Relaxing video games can produce overall mood improvements and make players more willing to help other people [38]. Also, playing casual video games, such as PopCap's Bejeweled 2, Peggle, and Bookworm Adventures can improve mood and reduce symptoms of depression and anxiety [30].

### Exergames

Exergames [21] can motivate players to be more physically active by combining games and exercise together. Some commercial games can be considered exergames, such as Dance-Dance Revolution or Wii Sports; we refer to these as active video games (AVG) [1] to differentiate them from research-based exergames. Researchers have designed a variety of exergames. Some games use custom sensors, such as in Ping Pong Plus [15] and Breakout for Two [21]. Others have integrated standard exercise equipment, such as the bikes used in Life is a Village [41]. Exergames have also been developed that do not prescribe the type of exercise, but are based on the player's heart rate, such as Triple Beat [24] and Nenonen et al.'s biathlon game [22].

### Efficacy of Exergames

The goal of exergames is to create physically active play experiences. In general, researchers have shown that their exergames are fun, but do they have the same benefits as regular exercise? Research shows that many exergames can be utilized as part of an overall aerobic exercise program because in a 30-minute exercise session, a player's heart rate and caloric expenditure are both within the American College of Sports Medicine recommendations for daily physical activity [34]. However, in another study that investigated the relative efficacy of Wii games and their real life sports counterparts, it was shown that the energy that players used to play active Wii Sports games was not of high enough intensity to reach the recommended daily amount of exercise in children [10]. A meta-analysis of AVG play confirms that exertion is well below thresholds for vigorous-intensity exercise [1]. One main problem with exergames that use accelerometer-based input is that players can 'cheat', by not exerting themselves to play, but simply moving the device in the appropriate pattern.

### Acute Cognitive/Mood Benefits of Exergame Play

Whether exergames can provide similar cognitive and psychological benefits as exercise is controversial. Given that the benefits stem from the aerobic exercise, we can assume that the exergames need to provide a level of aerobic activity to produce cognitive benefits, which most

do not do (see previous section). However, using a modified flanker task, O’Leary et al. [23] show that exergames (WiiFit) cannot exert the same benefits to brain and cognition as traditional exercise even though there was no difference in heart rate produced during play [23]. Staiano et al. [36], however, show cognitive benefits of Wii Active play in terms of visual spatial skills using the Bender-Gestalt test and executive functioning using the Delis-Kaplan Executive Function Scale [36]. Neither WiiFit nor Wii Active are considered to be games in the traditional definition [31], but rather are interactive exercise applications, so it is still unclear as to whether exergame play yields cognitive benefits. Russell et al. [28, 29], show that exergames can have a positive effect on mood.

### Casual Games

There are many definitions for casual games and the community has yet to converge on a final definition [17]. There is general agreement that for a game to be considered casual, it must: be easy to learn with limited instructions and simple rules and controls [16,44]; have short play times [45] and allow players put the game on hold [16]; and should not contain objectionable content [44] to appeal to a broad range of players [45]. Therefore, games such as Tetris and Bejeweled can be considered as casual games.

### Casual Exergames

Casual exergames apply the principles of casual game design to the design of exergames. Specifically casual exergames are defined as computer games that players can learn easily and access quickly, using simple rules and special game mechanics, to motivate them to exercise at a moderate intensity for short periods of play [42].

Some argue that exergames developed for gaming consoles, such as Wii Sports, can be considered casual exergames because they are easy to learn, use simple controls, and are family friendly. However, as previously described, many commercial exergames do not provide the required moderate-intensity exercise to be considered a casual exergame by our standards. In addition, if casual games are to be played in short play periods, they must have minimal setup time [44]. If setting up a console game requires even five minutes to boot the system, navigate menus, and calibrate controllers, then it is not in line with the duration of play expected of a casual game. Finally, the accessibility of gaming consoles, which are generally kept in domestic environments, limits their use as systems on which to play casual exergames during breaks at work or school.

Some smartphone games can be considered as casual exergames. For example, Jog Hop ([www.joghop.com](http://www.joghop.com)) is played by jogging, hopping and ducking, is described as being able to be played anytime and anywhere for a quick workout, and is targeted at kids and their families. However, like other accelerometer-based games, players can cheat the exercise aspect by moving the iPhone/iPad up and down instead of jumping and hopping to play the game.

Previous research into the exertion produced by playing casual exergames has mixed results; if insufficient exertion is produced, we cannot expect acute cognitive benefits.

### STUDY 1

To investigate the potential benefits of short bouts of casual exergame play, we compared our casual exergame to a sedentary version of the game played using a mouse, and exercise on a treadmill. We studied the efficacy of exercise, user response, and the cognitive and affective benefits.

### Experimental Conditions

Our study had three conditions. In the casual exergame condition, participants played the game using their body as the controller. Movements were sensed using a Microsoft Kinect sensor. In the sedentary condition, they played the game using a mouse as a controller. In the exercise condition, they did not play the game at all, but ran on a treadmill. In this condition, we checked their heart rate every minute and adjusted the speed and incline of the treadmill to keep them within 64-76% of their target heart rate, representing moderate-intensity activity (Figure 1).



Figure 1. Three conditions (L-R): Kinect, Mouse, Exercise.

### Task: GrabApple Game

GrabApple is a casual exergame that can be played in 10-minute sessions. For a complete description, see [42].



Figure 2. Screen shot of the GrabApple game.

In GrabApple (Figure 2), the goal is for players to pick up falling red and green apples and avoid touching the falling bombs. Apples and bombs are picked and touched using a virtual hand on the screen. There are two versions of GrabApple – in the Kinect version of the game, the virtual hand is controlled through the movement of the player’s body, using the player’s own body weight as resistance to

generate exercise. We use game mechanics to motivate people to jump, duck and move around. For example, players can get a bonus score by jumping or ducking to pick up the apples. Also, if players keep picking up the same color of apple, there is score multiplier that encourages a lot of movement. The hand can only hold five apples. After that, players need to jump to put the hand into the apple bag. In the mouse version of the game, we use a regular mouse to control the virtual hand on the screen.

### Procedures and Methods

The study took place over four consecutive days. On Day 1, participants were introduced to the study, gave informed consent, and were screened for colour vision deficiencies (CVD) using an online version of the PseudoIschromatic Plate Ishihara Compatible (PIP), because people with CVD perform worse on the Stroop test [18], which we used as a cognitive measure. Participants were also screened using the Physical Activity Readiness Questionnaire (PAR-Q) to look for risk factors that may be exacerbated by exercise.

After completing a demographics questionnaire, we introduced participants to two questionnaires used in our study: The Borg Rating of Perceived Exertion (RPE) [2], which is used to measure perceived exertion; and the Self-assessment Manikin (SAM) [3], a pictorial 9-point scale that is used to self-report affective states via valence (feelings of pleasure or displeasure) and arousal (activation of feeling). We also introduced them to the Stroop Color and Word Test [20] that we used to measure cognitive performance and had them complete a training version. Finally, we explained the game rules and the experiment conditions, after which players trained in the Kinect and Mouse versions of GrabApple for one minute each.

On Days 2, 3, and 4, participants completed one of the three experiment conditions (Kinect, Mouse, Exercise). Order of condition was fully counterbalanced across all participants to minimize learning effects. Participants completed the experiment at the same time each day and were asked not to perform exercise prior to the study each day or consume caffeine or smoke for three hours prior to each session.

Participants began each session by completing the SAM. They then performed that day's condition for 10 minutes. During the activity, they wore a heart-rate monitor (Garmin Forerunner 110) that measured their heart rate and the approximate number of Calories (kcal) burned. Then, participants filled out the SAM and the Borg RPE scale. After 5 minutes of recovery time, participants performed the Stroop test, then the post-condition questionnaire.

### Stroop Color and Word Test

The Stroop Color and Word Test [20] has three tasks, each consisting of 100 items. Task 1, the word test, has a list of five color names printed in rows and columns in white text on a grey background. Task 2, the color test, has a pattern of four X characters (i.e., XXXX) written in the same

colors as the color names on the first page. Task 3, the color-word test, has the color names of Task 1, but written in a color that conflicts with the color name (e.g., the word "BLUE" is printed in red ink). In the last task, participants need to say the color that the word is printed in, not the word itself. In all tasks, participants are required to read their answers out loud as quickly and accurately as possible. The pattern of items is random except that no word is allowed to follow itself in a single column (Figure 3). Participants were required to correct errors before moving on to the next item. The experimenter would notify players that an error was made by tapping on the screen; however, players usually self-corrected without prompting.

A computer version of the Stroop Color and Word Test was presented on a 20-inch monitor. Four versions of the test were created for this study; the first was used for training and the others were used on the three experiment days. The four versions were presented in a single order to balance across the three experimental conditions. The software recorded the time taken to complete each task.



Figure 3. First five lines of the 100-item Stroop Word and Color Test. Tasks 1-3 (from left to right).

### Participants

Twenty-four participants (13 males), aged 19 to 30 (mean of 24) were recruited from a local university. Seven are native English speakers, whereas the rest speak English as a second language (11 Chinese, 4 Iranian, 1 Ukrainian and 1 Nederlander participant). Thirteen of the participants played video games at least weekly; the others played only a few times per month or year. None of our participants regularly played games using the Kinect.

When asked about exercise, 11 participants performed 30 minutes of sustained physical activity per day and 19 performed 30 minutes at least 2-3 times per week. Half of the players said that they do not have time or are too lazy to complete the daily-recommended amount of exercise and 9 said that their lack of exercise was due to being tired from other activities (e.g., work and family). When asked if they take regular breaks during the workday, half of our players said that they take breaks every half hour to two hours. The others reported that they seldom took breaks.

### Apparatus

The game was played on a Windows 7 PC with a 20-inch monitor. A low resolution (800×600) was used as players stood about 1.5m from the display in the Kinect condition.

### Data Analyses

We performed a repeated-measures MANOVA on the dependent measures of %maxHR, perceived exertion,



Calories, and Stroop task completion time. with experiment condition as a factor (Kinect, Mouse, Exercise) Pairwise comparisons used the Bonferroni method of correction and all tests were conducted with  $\alpha=.05$ . When the sphericity assumption was violated, Huynh-Feldt's method of adjusting the degrees of freedom was used. Questionnaire responses (including SAM) were analyzed with Friedman's Analysis of Variance of Ranks, with pairwise comparisons made with Wilcoxon Signed Ranks Tests.

## Results of Study 1

We present our results in terms of exertion, participant responses, affective states, and cognitive benefits.

### Exertion

The American College of Sports Medicine defines moderate-intensity exercise as 64-76% of maximum heart rate ( $\text{maxHR}=220\text{-age}$ ) [37]. The average %maxHR of our players is in Table 1. These values are within the range of moderate-intensity exercise for the Kinect and Exercise conditions. The differences in %maxHR were significant ( $F_{1.7,38.1}=195.4$ ,  $p\approx.000$ ,  $\eta^2=.90$ ). Pairwise comparisons showed that the Mouse game produced significantly lower %maxHR than the Kinect game ( $p\approx.000$ ) and Exercise ( $p\approx.000$ ), and that there was no significant difference between Kinect and Exercise ( $p=.110$ ).

The average Calories burned in the 10 minutes of activity are shown in Table 1. If we assume play for three 10-minute bursts/day, the average Calorie expenditure would be 291, 259, and 81 for the Kinect, Exercise, and Mouse conditions respectively, which exceeds the recommended 200 Calories per day that adults should burn through aerobic exercise [26] for the Kinect and Exercise conditions, but not the Mouse condition. The differences in Calories burned were significant ( $F_{2,46}=135.8$ ,  $p\approx.000$ ,  $\eta^2=.86$ ). As with %maxHR, pairwise comparisons revealed that the Mouse game produced significantly lower Calories burned than the Kinect game ( $p\approx.000$ ) and Exercise ( $p\approx.000$ ), and that there was no significant difference between Kinect and Exercise ( $p=.157$ ).

	% of Maximum Heart Rate	Calories Burned	Borg RPE
Kinect	74.5 (9.8)	97.2 (20.7)	12.5 (1.6)
Exercise	69.9 (3.7)	86.2 (15.9)	11.7 (1.0)
Mouse	42.7 (5.3)	26.9 (10.6)	6.8 (0.8)

**Table 1. Means and SDs for measures of exertion.**

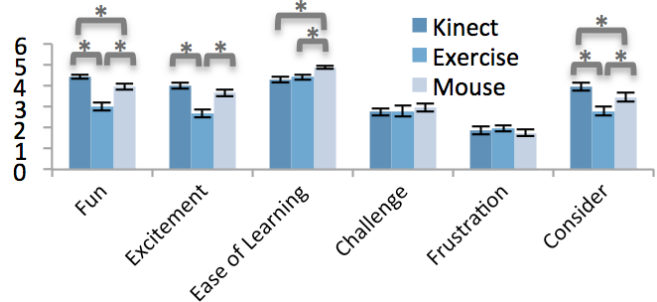
The average Borg Rating of Perceived Exertion after each activity is in Table 1. The Kinect game produced perceived exertion values within the recommended intensity for improving aerobic capacity (12-13: somewhat hard to 15-16: hard) [35]. The differences in perceived exertion were significant ( $F_{2,46}=166.1$ ,  $p\approx.000$ ,  $\eta^2=.88$ ). Again, pairwise comparisons showed that the Mouse game produced significantly lower perceived exertion than the Kinect game

( $p\approx.000$ ) and Exercise ( $p\approx.000$ ), and that Kinect and Exercise were not significantly different ( $p=.116$ ).

### Participant Responses

We asked participants to rate six aspects of the game (fun, excitement, ease of learning, challenge, frustration, and whether they would consider to play it if they had a 10-minute break) on a 5-point Likert scale (1=strongly disagree, 5=strongly agree) after playing each version. The results are shown in Figure 4. Correlations (Spearman's  $\rho$ ) of ratings showed significant correlations for excitement with fun ( $\rho=.801$ ,  $p\approx.000$ ) and challenge ( $\rho=.247$ ,  $p=.037$ ).

Friedman's test showed significant differences in ratings for fun ( $\chi^2_2=27.7$ ,  $p\approx.000$ ), exciting ( $\chi^2_2=27.9$ ,  $p\approx.000$ ), easy to learn ( $\chi^2_2=13.5$ ,  $p=.001$ ), and whether they would consider doing it in a break ( $\chi^2_2=15.8$ ,  $p\approx.000$ ), but not challenging ( $\chi^2_2=2.0$ ,  $p=.373$ ) or frustrating ( $\chi^2_2=1.8$ ,  $p=.416$ ). Pairwise comparisons showed that the Kinect version was perceived as more fun ( $p=.019$ ) and less easy to learn ( $p=.001$ ) than the mouse version, and more fun ( $p\approx.000$ ) and more exciting ( $p\approx.000$ ) than exercise. The mouse version was perceived as more fun ( $p=.001$ ), more exciting ( $p\approx.000$ ), and easier to learn ( $p=.005$ ) than exercise. In addition, players were more likely to consider playing the Kinect version than the mouse version ( $p=.049$ ) or exercise ( $p=.001$ ), and were more likely to consider playing the mouse version than exercising ( $p=.042$ ). Other pairwise comparisons were not significant.



**Figure 4. Means ±SE for participant ratings after each condition in study 1 (higher is stronger agreement), \* $p<.05$ .**

### Affective Benefits

Participants rated their arousal and valence before and after each condition. There was no significant difference in pre-condition arousal or valence but there was a significant difference in both post-condition arousal and valence (Table 2). Pairwise comparisons revealed that players felt most aroused after playing the Kinect game, followed by Exercise, then the Mouse game. All differences were significant (all  $p<.035$ ). Players felt more positive following the Kinect game than either the Mouse game ( $p=.031$ ) or Exercise ( $p=.001$ ), and there was no difference between valence after the Mouse game or Exercise ( $p=.480$ ).

	Arousal (pre)	Valence (pre)	Arousal (post)	Valence (post)
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Kinect	4.46 (1.1)	5.79 (1.3)	7.00 (1.4)	7.08 (1.0)
Exercise	4.42 (1.2)	5.83 (1.5)	6.25 (1.0)	6.12 (1.2)
Mouse	4.38 (1.7)	5.96 (1.5)	5.54 (1.4)	6.42 (1.5)
$\chi^2(2), p$	0.38, .829	0.09, .958	17.4, .000	10.9, .004

**Table 2. Means (SD) for pre- and post-condition arousal and valence on a 9-pt scale. Results of ANOVA.**

#### *Cognitive Benefits*

There are three tasks in the Stroop test. We recorded the time that participants completed each task (100 items) [9].

A repeated-measures ANOVA showed no significant differences in performance on Task 1 ( $F_{2,46}=3.0, p=.060, \eta^2=.12$ ), Task 2 ( $F_{2,46}=2.5, p=.097, \eta^2=.10$ ), or Task 3 ( $F_{2,46}=1.3, p=.295, \eta^2=.052$ ). As Table 3 shows, the variation between participants was very large. In fact, the percentage of variance explained by the factor of participant was 97% for all three Stroop tasks. Rather than increasing our sample size for the entire study to reduce the effects of individual variation, we investigated whether there is reason to consider that the Kinect condition would produce better performance than the Mouse condition through planned pairwise comparisons using two-tailed paired-samples t-tests. The results suggest that there is some cognitive advantage to the Kinect condition for all of the Stroop Tasks (Task 1:  $t_{23}=2.0, p=.052$ , Task 2:  $t_{23}=2.6, p=.015$ , Task 3:  $t_{23}=2.1, p=.044$ ). As expected, there appears to be no cognitive advantage to the Kinect version over exercise on a treadmill for any of the Stroop tasks (Task 1:  $t_{23}=0.8, p=.440$ , Task 2:  $t_{23}=0.2, p=.857$ , Task 3:  $t_{23}=0.8, p=.422$ ).

	Task1	Task2	Task3
Kinect	38.8(6.4)	61.2(11.0)	88.3(14.5)
Exercise	39.2(6.9)	61.5(11.7)	90.0(18.3)
Mouse	40.3(7.5)	63.2(11.9)	91.4(16.7)

**Table 3. Means and SDs for Stroop task 1,2,3.**

#### **Discussion of Study 1**

In Study 1, we found that players of Kinect-based GrabApple had heart rates within targets for moderate-intensity exercise (75% of max), burned an average of 97 Calories, and had perceived exertion levels of 12.5 on the Borg Rating of Perceived Exertion, where 12-13 represents “somewhat hard”. These values were significantly higher than after playing a sedentary version of the game, but not different than exercising on a treadmill. Playing our casual exergame for 10 minutes produces efficacious exercise.

We found that after playing our casual exergame, players felt more positive and aroused than after playing the mouse version or exercising. Players reported that the Kinect game was more fun than the mouse game or exercising. Although they found it more difficult and not as easy to learn as the mouse version, they were more likely to consider playing the casual exergame during a break in their workday than playing either the mouse version or exercising.

Although our ANOVA results did not show significant differences in cognitive performance on a Stroop task, our planned comparisons with a t-test showed an improvement in performance after playing the Kinect game as opposed to the Mouse game. This effect was too small to show up in an ANOVA with 24 participants. Upon further investigation, we found that performance on the Stroop task is subject to differences due to first language. Because our participants repeated versions of the test over the course of four days, their performance was likely to improve over the course of the study. The issue is that performance improvements are quite variable for people who do not speak English as their first language. For example, in Task 3, the interference task, the time for participants to complete the task ranged from 54 to 135 seconds. 70.8% of our participants were not native English speakers. Rather than discount their data, reduce the power of our experiment by looking at between-participant differences only on the final day of the experiment, or increasing our sample size significantly, we chose to further explore the potential cognitive benefits of our casual exergame in a second study. The planned comparisons of the Stroop results demonstrate that there may be a systematic (but not significant) effect of casual exergame play on cognitive performance, thus we conducted a second study to better explore this effect with cognitive tests that are not susceptible to large individual variation in performance due to language.

#### **STUDY 2**

In this study, we explored the potential cognitive benefits of casual exergame play as compared to playing an identical, but sedentary, version of the game. Because Study 1 revealed that the casual exergame produced exercise intensities similar to exercise on a treadmill, we focused on only the two versions of the game in Study 2 – the casual exergame version, played using the body as the game controller as sensed by the Kinect, and the sedentary version, played using the mouse as the controller. In addition, we chose two cognitive tests that are not subject to whether players speak English as their first language – the d2 test of attention and the WRAT4 Math Computation test.

#### **Procedure and Methods**

The procedures for Study 2 were identical to Study 1, with few exceptions. Because players completed only two conditions, the study happened over two days instead of four (the study introduction occurred on Day 1). Also, players were introduced to the d2 test of attention and the WRAT4 Math Computation test rather than a Stroop test. Finally, we did not require players to complete a CVD test, as neither cognitive test is affected by CVD. The experimental apparatus was the same as used in Study 1.

#### **d2 Test of Attention**

The d2 Test of Attention measures processing speed, rule compliance, and quality of performance, estimating attention and concentration [4]. The test items consist of the



letters d and p arranged in 14 lines of 47 characters. The letters have one to four dashes, arranged either individually or in pairs above and below the letter. Subjects are required to cross out any letter 'd' with two dashes arranged in any combination above or below the 'd'. We allowed participants 15 seconds to complete each line.

The test is scored such that five metrics are produced in three categories, including: 1) Speed – the total number of items processed (TN); 2) Accuracy – the total number of errors (E), and the percentage of errors (E%); and 3) Overall Performance – the total number of items scanned minus error scores (TN-E), and the number of correctly crossed out relevant items minus the errors of commission (CP). TN-E and CP are indicators of concentration.

#### WRAT 4 (Math Computation Subtest)

The Wide Range Achievement Test 4 (WRAT4) assesses basic academic skills through two equivalent forms designed for pre- and post-intervention testing [39]. We used the Math Computation test to measure the ability to perform basic computations through calculating written math problems. We gave each participant 15 minutes to complete the test. The test score is the number of correct responses. We fully balanced the presentation of the two versions of the test across the ordering of conditions.

Although the WRAT4 measures achievement, given on two consecutive days, it can indicate concentration and focus rather than an improvement in mathematics ability.

#### Participants

Twenty-four participants (14 males), aged 19 to 33 (mean of 25), who did not participate in Study 1, were recruited from a local university. Seventeen of the participants played video games at least weekly; the others played only a few times per month or year. Eight participants had experience playing games with a Kinect, but not on a regular basis.

When asked about their daily exercise, only one participant got 30 minutes of sustained physical activity per day and 17 participants performed 30 minutes of exercise at least 2-3 times per week. Participants reported reasons why they do not complete the daily-recommended amount of exercise: 9 because of busyness, 3 because of laziness and 6 because of tiredness from other activities (e.g., work and family). When asked if they take regular breaks during the workday, 13 of our players take a break every half hour to two hours.

#### Data Analyses

Paired-samples T-tests ( $\alpha=.05$ ) were used to compare the exertion and cognitive performance of the players in the two conditions. Based on Study 1 (and related research), we expected that players would exert more energy, and have better cognitive performance after playing the Kinect version, so we used one-tailed tests. Wilcoxon Signed Ranks tests were used to compare results from questionnaires on player preference and affective state.

## Results of Study 2

We first present results for exertion, followed by player preference, affective state, and cognitive performance.

#### Exertion

As expected, playing the Kinect version of the game was more exertive than playing the Mouse game as measured by %maxHR ( $t_{23}=17.2$ ,  $p\approx.000$ ), Calories burned ( $t_{23}=11.4$ ,  $p\approx.000$ ), and the Borg RPE ( $t_{23}=15.2$ ,  $p\approx.000$ ). See Table 4.

	% of Maximum Heart Rate	Calories Burned	Borg RPE
Kinect	72.9 (11.7)	85.6 (26.6)	12.9 (1.8)
Mouse	41.3 (8.4)	25.9 (10.0)	7.2 (1.1)

Table 4. Means and SDs for measures of exertion.

#### Participant Responses

Non-parametric correlations (Spearman's  $\rho$ ) of all ratings showed significant correlations for: fun with excitement ( $\rho=.679$ ,  $p\approx.000$ ) and challenge ( $\rho=.327$ ,  $p=.024$ ); excitement with challenge ( $\rho=.380$ ,  $p=.008$ ); and frustration (inversely) with fun ( $\rho=-.474$ ,  $p=.001$ ), excitement ( $\rho=-.477$ ,  $p=.001$ ), and challenge ( $\rho=-.393$ ,  $p=.006$ ). Players found the Kinect version to be significantly more challenging ( $Z=2.3$ ,  $p=.026$ ), and the mouse version easier to learn ( $Z=2.1$ ,  $p=.034$ ). There was no significant difference in terms of ratings for fun ( $Z=0$ ,  $p=1.0$ ), excitement ( $Z=0.8$ ,  $p=.430$ ), or frustration ( $Z=0.3$ ,  $p=.763$ ), or whether they would consider playing it in breaks at their work ( $Z=1.2$ ,  $p=.246$ ). See Figure 5.

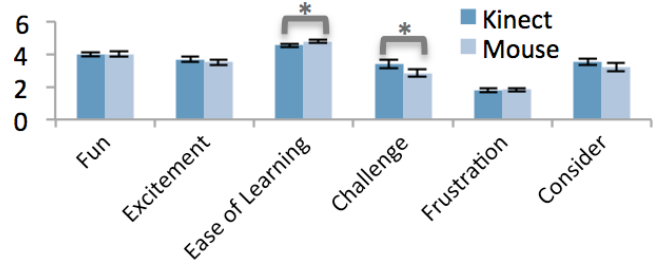


Figure 5. Means ±SE for participant ratings after each condition in study 2 (higher is stronger agreement). \* $p<.05$

#### Affective State

Neither arousal nor valence were different prior to playing. Arousal was significantly higher after playing the Kinect version than the mouse version, but there was no significant difference in post-play valence (see Table 5).

	Arousal (pre)	Valence (pre)	Arousal (post)	Valence (post)
Kinect	4.33 (1.9)	5.83 (1.2)	7.63 (1.4)	7.33 (1.1)
Mouse	4.29 (1.5)	6.12 (1.1)	6.42 (1.9)	7.04 (1.2)
Z, p	0.11, .909	0.90, .369	3.67, .000	1.25, .210

Table 5. Means and SD for arousal and valence. Results of Wilcoxon Signed Ranks tests.

#### Cognitive Performance

Cognitive performance results are presented for each test.

**d2 Test of Attention.** Participants performed significantly better on the d2 Test after playing the Kinect version of the game than after playing the mouse version of the game in terms of speed (TN) and overall performance (TN-E and CP). However, there were no significant differences in terms of accuracy (E, E%). See Table 6.

	TN	E	E%	TN-E	CP
Kinect	479 (57)	16 (14)	3.3 (2.7)	463 (51)	186 (23)
Mouse	456 (65)	21 (18)	4.6 (3.7)	435 (61)	171 (30)
$t_{23}, p$	2.27, .017	1.38, .091	1.6, .066	2.38, .013	2.25, .018

**Table 6. Means and SD for d2 measures. Results of t-tests.**

**WRAT4 Math Computation Test.** Participants scored higher on the math test after playing the Kinect version of the game (Mean=49.9, SD=3.4) than after playing the mouse version (Mean=48.2, SD=6.1). This difference was statistically significant ( $t_{23}=1.769, p=.045$ ).

## DISCUSSION

Our results can be summarized in six findings. Playing a casual exergame for ten minutes results in:

- Exertion levels similar to running on a treadmill and significantly higher than playing a sedentary casual game;
- Improved performance compared to a sedentary casual game on three cognitive tests that measure concentration;
- Similar cognitive benefits to traditional exercise on a treadmill as measured by a Stroop test;
- Increased arousal compared to a sedentary casual game or treadmill exercise;
- Increased valence compared to a sedentary casual game (Study 1 only) or treadmill exercise;
- Greater perceived fun than a sedentary casual game (Study 1 only) or treadmill exercise.

Thus, our results show that playing a casual exergame for ten minutes at a time can produce acute cognitive benefits, improve affective states, and produce physical activity levels similar to traditional exercise on a treadmill.

## Significance of our Findings

Our results are the first to show that a casual exergame, played for only ten minutes, can produce measurable acute cognitive and affective benefits.

The cognitive improvements are statistically significant. Performance improved in the Stroop task by 3.5%, in the d2 test by 14.2% (on average), and in the math test by 3.4%. These are in line with results from previous research on the acute cognitive benefits of traditional exercise. Because of the potential benefits to people at work, in school, or at home of even a 4% increase in ability to concentrate, our findings have both statistical and practical significance.

It is important to note that improved performance on these tests does not indicate an improved ability, but increased focus and attention; participants were not better at math

after playing our casual exergame, but were better able to focus on their math test to improve their performance. We do not claim that casual exergame play results in improved cognitive abilities, but that the temporary improvements in attention can, in turn, help people better show their abilities.

## Limitations and Opportunities

Our results clearly show acute cognitive benefits of casual exergame play; however, there are limitations in what we can infer from our studies and new questions that are raised.

First, the improvements were shown in tests administered five minutes after exercise; we do not know how long these acute benefits last. The administration of the two cognitive tests in Study 2 took 20 minutes, so we can assume that the benefits last at least that long. A 30-minute advantage for 10 minutes of exercise may be a good investment for an exercise-induced cognitive pick-me-up, but future work will need to study the duration of cognitive benefits.

Second, the measured cognitive benefits were acute, i.e., short and temporary. Whether repeated casual exergame play over the long term would result in the general cognitive benefits seen in people with good aerobic fitness [8] remains to be seen.

Third, our players were motivated to play the casual exergame for ten minutes at a moderate-level of intensity. Outside of the context of our experiment, we do not know how much physical effort players would put into playing GrabApple. We also do not know how motivated people would be to play a casual exergame repeatedly throughout the day to improve their focus and concentration, or to play a casual exergame repeatedly over the long term. Previous work suggests that active video game play declines over time [1]. If the game does not engage players for repeated play, then the temporary cognitive benefits of casual exergame play will not be achieved. The novelty of the Kinect may have affected the players' perceptions of fun; whether the results hold after repeated play requires study. Maintaining engagement and encouraging repeated play through game design is part of our current line of research.

Fourth, we saw improvements by comparing performance after playing an exergame to performance after a mouse-based game. We are currently investigating the size of the benefit by studying improvements to baseline performance.

Finally, we compared the exertion produced by our casual exergame to that produced from exercise on a treadmill. In the exercise condition, we forced participants to exercise at a moderate intensity by adjusting the speed and incline of the treadmill every minute. We cannot anticipate the results if participants had been allowed to exercise at their own pace. We can assume that participants who were lazy and did not achieve target heart rates indicative of moderate-intensity exercise would not show cognitive benefits or the benefits would be reduced. We do not know whether

vigorous-intensity exercise would strengthen or reduce the exercise-induced acute cognitive benefits.

### **Implications for Casual Exergame Design and Use**

We show that playing casual exergames produces acute cognitive benefits; however, we also argue that for people to choose to play, the casual exergames must be convenient and accessible. This requirement for a low overhead to setup presents a challenge for game design.

As new activity sensors become integrated into technology, casual exergames can move beyond the desktop, becoming more convenient to play. With smartphone-based games, people could access games quickly and play during natural breaks in their day, such as when waiting for a bus. Casual exergame designers will be faced with a challenge of creating games that produce moderate-intensity exercise, but are not considered socially awkward. People playing casual exergames in the street or at work may not want to perform exaggerated motions, whereas motions such as jumping or walking may be considered less awkward. This issue of social awkwardness is complicated by casual exergame players not sending cues that they are engaging in exercise via specific clothes; the games are intended to be played with little overhead to set up, thus people would be playing them in regular attire. As with other behaviours, if enough people play casual exergames, the motions associated with play will be regarded as socially acceptable.

One way to make casual exergames ubiquitous and to motivate play is to deploy them in common public break locations, such as coffee shops or bus stops. We are interested in how casual exergame deployments in schools, workplaces, and homes can help motivate people to play repeatedly. In schools, kids who enjoy playing games could refocus before each class or at known lull times. At home, kids could play casual exergames when they feel tired before starting their homework in the evening. Deploying casual exergames in break rooms at workplaces would help workers get physical benefits of exercise in a manageable way and also refresh their minds. Employees who exercise during lunch breaks report better work performance and mood improvements compared with workdays that they did not exercise [5]. With casual exergame deployment, the cognitive benefits that we showed using standard tests in a lab may translate into better performance at school or work. Taking 10 minutes to exercise will be good for a person's health, but from an employer's perspective, the improved performance would need to offset the time spent exercising.

### **Future Work**

Our results for cognitive benefits after casual exergame play are encouraging, and there are three main research directions that we plan to pursue to establish casual exergames as a method for improving cognitive health. First, the cognitive benefits we found are measured through outcomes; people were better able to concentrate, improving their performance on a test of ability. For future

work, we may directly measure the level of focus exhibited post-play through neuroimaging techniques. Second, there are special populations who would benefit from temporary improvements in concentration. We are working with children with fetal alcohol spectrum disorder – which is generally co-diagnosed with attention deficit hyperactivity disorder – to study potential acute cognitive benefits of casual exergame play for this population. Finally, to explore the practical significance of our findings, we are working with schools to explore the long-term engagement of casual exergames, the duration of experienced cognitive benefits, the outcome of repeated play sessions during the day, and the general benefits that accumulate over regular play.

### **CONCLUSION**

Acute cognitive benefits, such as temporary improvements in concentration, can result from as few as ten minutes of exercise; however, most people do not take exercise breaks throughout the day. Casual exergames can motivate people to exercise in short bursts multiple times per day. Through two studies, we show acute cognitive benefits of the casual exergame over the sedentary version (but not treadmill exercise), demonstrated by improved cognitive performance on tests that require focus and attention. Improvements were found in players' affective states after playing the casual exergame, which produces similar exertion levels as treadmill exercise, but is perceived as more fun.

Played repeated times throughout the day, casual exergames have the potential to help people improve their focus at school, home, and in the workplace. Casual exergame designers have an opportunity to improve both the physical and cognitive health of their players.

### **ACKNOWLEDGMENTS**

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## CHAPTER 4

### 4 ENGAGING PRE-ADOLESCENTS IN PHYSICAL ACTIVITY WITH CASUAL EXERGAMES

#### 4.1 OVERVIEW OF CHAPTER 4

In chapters 2 & 3, we explored the physical activity levels and the acute cognitive benefits produced by playing causal exergames for short periods of time. Through our exploration, it is clear that casual exergames worked well in terms of providing physical exertion and acute cognitive benefits among adults as well as providing an enjoyable experience. In chapter 3, we also discussed the potential deployment of casual exergames in school settings to help kids refocus throughout their day.

Exploring causal exergame play among children, especially in school settings, to explore the long-term engagement of casual exergames was identified as an important research direction in chapter 3. In this chapter, we explored the feasibility for casual exergame deployment in schools.

There are three main advantages for deploying causal exergames at school. First, most teenagers are familiar with video games [1], and they enjoy playing video games, so using game elements might be a good approach to motivate teenagers to perform the physical activities. Second, casual exergames are games that are designed to be played in short periods of time so they can be easily integrated into players' daily lives, such as playing casual exergames during recess and class breaks. Third, casual exergames can produce sufficient exertion levels to produce acute cognitive benefits so it might be a good way to help children to refocus during their downtime and fully achieve their academic performance at school.

In this chapter, we examined the physical exertion produced by, the acute cognitive benefits that result from and the player experience of playing our casual exergame, the sedentary version of our game, and traditional exercise. Also, we provided insights into children's attitudes about the impact of exercise on concentration and teachers' opinions on physical education and casual

exergame deployment in classrooms. Based on the results of our study, we further provided an initial analysis of the role of casual exergames in the classroom. With the proper casual exergame design, we argue that casual exergames are feasible to be deployed at school to provide a fun and short workout for students.

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# Engaging Pre-adolescents in Physical Activity with Casual Exergames

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## ABSTRACT

There are many positive benefits of exercise, from physiological reductions in obesity and cancer risk to psychological reductions in anxiety and improvements to cognition. Healthy exercise habits instilled during childhood are strong predictors of healthy lifestyles later in life. However, faced with academically-motivated achievement standards, schools are cutting traditional scheduled exercise in favour of additional classroom time, creating a need for physical activities that can be integrated into short breaks in the school day, and that provide sufficient motivation for adolescents to pursue on their own time. Casual exergame play has been shown to provide exertion levels at the recommended values, even when played in short bursts of only 10 minutes. In this paper we describe the deployment of a previously-described casual exergame, GrabApple, with a group of pre-adolescent students from a local school. We show that students preferred the game to traditional exercise, that the game was able to generate appropriate levels of exertion in pre-adolescents, and that students have a sophisticated understanding of the role of exercise in their lives and school through a semi-structured experiment and a series of follow-up questionnaires. We further provide an initial analysis of the role of causal exergames in the classroom through surveys of the students' teachers. We find overall that casual exergames have a place in the classroom to supplement traditional exercise activities both during class times and during breaks in the school day.

## INTRODUCTION

Exercise and physical activity have several positive well-documented effects on children, including short-term effects such as improvements in cognition [30] and long-term improvement in overall health; however, a lack of activity during childhood can lead to obesity and associated chronic conditions [32]. As a response to declining levels of physical activity among children and an increase in childhood obesity rates, different approaches towards encouraging physical activity among children and teenagers have been introduced, including individual, community, and school-based initiatives [5,24][38]. For primary and secondary schools in particular, initiatives that integrate physical activity beyond physical education (PE) classes into students' schedules have been proposed [5]. While these approaches have been successful with children, encouraging exercise among pre-teen and teenagers is particularly difficult as attitudes towards exercise shift in the teenage years. Rather than regarding exercise as a fun activity, teenagers consider it a chore [10], and this attitude is accompanied by observable changes in

behavior. Children in elementary school frequently engage in physical activity during recess and break times, (e.g., running and playing), but most teenagers stop engaging in unstructured play [5], and teachers struggle to encourage sufficient physical activity among them. Often, teenagers do not attend PE class regularly [46], and many fail to reach recommended levels of activity throughout the week.

Research has shown that exergames – games that integrate physical activity into play – can motivate teenagers to be more active [23] by adding game elements to workout routines. Exergames have been successfully introduced to high school students [21]; however, many exergames require lengthy setup routines and are designed for prolonged play sessions, reducing their utility in classroom settings. To address this issue, we suggest the introduction of casual exergames, which are designed to be played in short bouts and can easily be integrated into players’ lives while producing sufficient exertion levels to meet current guidelines [45]. Furthermore, specifically designed casual exergames allow players to regulate exercise intensity, maintaining appropriate levels of exertion. Finally, casual exergames are designed to be played in short bouts and can be easily integrated into students’ recess time and class breaks; hence they are well suited to be played in short chunks in a school setting.

In this paper, we present a study with sixty-three students at the transition from childhood to adolescence playing the casual exergame GrabApple in a classroom-like setting. GrabApple has been shown to have acute cognitive benefits while providing a moderate-intensity workout among adults [12]; here we examine the deployment among pre-teens to determine whether casual exergames yield benefits similar to regular physical activity. Additionally, we provide insights into students’ and teachers’ attitudes on physical activity and exergames and provide additional insights into the design of casual exergames for classroom settings.

The results show that GrabApple can be applied to encourage physical activity among students, and that the game can be feasibly to be deployed in a classroom setting. The game yields workout intensities at target levels, and students’ responses show that they enjoy it. Furthermore, our results show that teachers are interested in integrating exergames into school routines, which is important as they constitute one of the primary stakeholders of exergame deployment in schools.

This paper makes two central contributions to the study of exergames in general, and educational exergames in particular. First we show that casual exergames can be deployed in a classroom setting, yielding effects similar to those shown in lab studies, and are considered enjoyable by students. Second, we investigate and report students’ and teachers’ attitudes towards exercise and exergames in a school setting and provide an overview of their opinions.



Casual exergames can be deployed in schools to make exercise enjoyable and accessible over short periods. We believe that casual exergames are a suitable means of fighting the increasingly sedentary behavior of teenagers at school. Casual exergames can be applied to support students in their learning efforts by leveraging the benefits of short, opportunistic bouts of exercise.

## **RELATED WORK**

The goal of our research is to consider the introduction of efficacious casual exergames into the classroom. As such, we cover literature on the general benefits of exercise, children's and adolescents' attitudes towards exercise, and related literature on exergames including casual exergames.

### **Physical Activity during Childhood and Adolescence**

Regular physical activity is crucial during childhood and adolescence, as it has a large impact on an individual's ability of maintaining a healthy lifestyle during adulthood [27]. In this section, we provide an overview of the benefits of exercise for children and teenagers, and summarize research on children and teens' attitudes towards physical exercise.

#### *Effects of Exercise on Children and Teenagers*

To get the potential benefits of physical activity, guidelines provided by the National Association for Sport and Physical Education (NAPSPE) recommends that children engage in more than 60 minutes of moderate to vigorous exercise a day. Exercise can be carried out in multiple short bouts lasting at least 15 minutes, including rest and recovery time [7]. However, according to the 2011 national Youth Risk Behavior Surveillance in United States, only about half of the children meet the exercise recommendations on five or more days per week [46]. Physical exercise can help prevent chronic disease, reduce the cholesterol ratio, increase bone density [32] and reduce obesity [11] in children. Regular exercise also has psychological and cognitive benefits. It has been shown that fitness through physical activity can enhance measures of children's psychological well-being, such as self-satisfaction and self-esteem [32]. Exercise has also been linked to a positive impact on children's mental function, including cognition and academic performance [37]. In addition to the general relationship between exercise and mental function, researchers have also shown acute (i.e., short and temporary) cognitive benefits and mood improvement in children [19,38,41] after bouts of activity. Both cognitive benefits and mood improvements can be found after performing as few as ten minutes of moderate-intensity exercise [17,43] in adults. Performing exercise in small chunks does not reduce the physical benefits as

research shows that the physical benefits of three moderate-intensity 10-minute bouts are similar to one continuous 30-minute bout [8,18,29].

### *Attitudes about Physical Activity*

Related work reports a decline in children's participation in physical activity at early adolescence [22,28], and points out that many factors can influence people's physical activity behavior [22]. One of the important predictors of people engaging in physical activity is attitude towards exercise [9]; in particular children will participate in physical activities when they have a positive attitude on physical activity [16]. Several studies have shown that integrating health education in classes, labs and readings can have positive impact on children's health attitude [6,14]. However, many schools (particularly in the U.S.) intend to improve students' academic scores by increasing time for core curricular subjects and decreasing PE [40]. Therefore, it is challenging for schools to allocate more time for physical activity during the school day [5].

### **Exergames**

Exergames [25] motivate players to be more physically active by combining game elements and exercise. Research-based exergames have integrated standard exercise equipment, such as bikes in Life is a Village [44] and custom sensors in Ping Pong Plus [20]. Also, some commercial games such as Dance Dance Revolution can be considered exergames [1]. In this section, we provide an overview of casual exergames and summarize research in the field of exergame deployment in school settings.

### *Casual Exergames*

Casual exergames are based on the insight that the daily amount of exercise necessary to obtain health benefits can be broken down into smaller chunks, while maintaining the positive effects [8,18,29,43]. To help people add these small chunks of physical activity throughout the day, casual exergames [13] apply the principles of casual game design to the design of exergames: most importantly, they allow players to engage in physical activity in short bouts. Specifically, casual exergames are defined as *computer games that players can learn easily and access quickly, using simple rules and game mechanics, to motivate them to exercise at a moderate intensity for short periods of play* [45]. Research on casual exergames has shown that as little as ten minutes of casual exergame play can produce moderate-intensity exertion levels, improving players' affective states and providing significant levels of acute cognitive benefits compared to sedentary casual games [12]. While these results are promising, prior work has only explored the benefits of casual exergames with adults in lab settings. This paper expands on the

approach by introducing casual exergames in a classroom setting, investigating whether benefits still exist when casual exergames are applied in a less controlled environment.

### *Exergames in Schools*

Prior work has addressed the deployment of exergames in school, especially through incorporation into PE classes. Lwin and Malik [23] argue that incorporating exergaming into PE lessons is more beneficial than regular PE as it can improve physical activity beliefs and behaviors. However, Sun [36] claims that incorporating exergames into PE may not produce health benefits, as exergames may not provide appropriate levels of physical activity, although students show higher situational interest. This position has merit research has shown that commercial exergames (e.g., Wii Tennis) do not produce sufficient exertion to meet current guidelines [15]. Other than applying commercially available games at schools, researchers have also introduced exergames using mobile phones and accelerometers to help students at school to fight sedentary lifestyles [21,26,42]. Although results suggest that these games can motivate students to become more active in the short term, instrumenting each user with body-mounted sensors is a complex and expensive approach, which might create challenges in deploying such games in schools.

While research results suggest that exergames cannot replace traditional physical activity in PE classes, the use of exergames seems to be a promising way to add extra physical activities during the school day. In this paper, we explore the deployment of a casual exergame in a classroom-like setting to investigate whether the characteristics of the genre will allow children to play games during breaks at school.

## **STUDY**

We conducted a study comparing the effects of exergame play, sedentary play and traditional exercise on school children to investigate the feasibility of casual exergames in a school setting. We were interested in physical exertion, cognitive effects, player experience and affective states, as well as students' and teachers' attitudes towards exercise and exergames in a classroom setting.

### **Participants**

Sixty-three grade seven children (29 boys) from a local elementary school participated in this study. Data of three participants had to be excluded (two children with disabilities, one was unable to participate). Participants ranged from 11 to 13 years old ( $M=12$ ). Seventeen of the participants reported that they played video games at least five or six days a week, six participants almost never played video games, and the majority of participants played 1-2 or 3-4 days per week. The majority of participants

were familiar with games that require physical activity (e.g., Xbox Kinect, PlayStation Move and Nintendo Wii).

Our participants were quite physically active. When asked about exercise, 22 of the participants reported engaging in physical activity outside of school on a daily basis, and only one participant almost never performed exercise outside of school. The remaining participants did exercise several days a week outside of school. In general, our participants were aware of benefits of physical activity. At school, they participate in the *Healthy Bodies Active Minds* (HBAM) program, which provides extra PE classes and teaches students background information on nutrition and activity.

We also invited the four high school teachers (three men) responsible for the students' program of study to provide insights into their students' attitudes towards physical activity. Their teaching experience spanned from kindergarten to grade eight.

### **The GrabApple Game**

GrabApple (Figure 1) is a casual game that can be played in a 10-minute session. For a complete description, see [45]. The goal of the game is to pick up falling red and green apples and avoid touching the falling bombs. Apples and bombs are picked and touched using a virtual hand on the screen. There are two versions of GrabApple – in the Kinect version of the game, the virtual hand is controlled through the movement of the player's body, using the player's body weight as resistance to generate exercise. The game mechanics motivate people to jump, duck and move around; for example, players receive a bonus by jumping or ducking to pick up the apples. Also, if players keep picking up the same color of apple, there is score multiplier that encourages additional movement. The hand can only hold five apples. After that, players need to jump to put the hand into the apple bag. In the mouse version of the game, a regular mouse is used to control the virtual hand on the screen, requiring no exercise to play.



**Figure 1. Screenshot of the GrabApple game.**

### **Experimental Conditions**

Our study had three conditions: In the exergame condition, participants were asked to play the casual exergame GrabApple, which uses the player's body as game controller. Movements were tracked using a Microsoft Kinect sensor. In the sedentary condition, participants played GrabApple using the keyboard and mouse. In the exercise condition, participants performed traditional exercise (e.g. rope skipping, climbing stairs and running short distances while avoiding obstacles) guided by a PE teacher. In all three conditions, participants wore a heart rate monitor.

### **Procedure and Methods**

The study methods and instruments were first approved by ethics offices at the University of Saskatchewan and the Saskatoon School District. All students and students' parents filled out informed consent and assent forms prior to arriving at the University campus. Students arrived at the university on the morning of a regular school day. Each student received an envelope with worksheets for recording their heart rate, surveys and a pencil. Next, we introduced the day-long overall activities to the group. Students filled out demographic, exercise attitude, and affective states surveys to provide baseline information (baseline surveys). Afterwards, we introduced the d2 Test of Attention, and students performed a baseline test. Finally, we divided the students into two groups: one group participated in the experiment in the morning, while the other group participated in the afternoon. When students did not participate in the experiment, they participated in a half-day workshop on programming fundamentals in Scratch.

The experimental group began the experimental protocol with a two-minute video explaining GrabApple. Afterwards, each participant put on a heart rate monitor (chest strap with wrist band display) with the help of their teachers if necessary and wrote down their resting heart rate on the worksheet. We divided the participants into three subgroups (8-12 students per group) and assigned each subgroup to a different condition (exergame, sedentary, exercise). The order of conditions was fully counterbalanced. Each group was accompanied by at least two teachers and three volunteers to supervise participants and administer the surveys. Participants in the exercise condition were in a separate room and guided by a PE teacher to ensure comparable levels of activity across groups. In each condition, participants performed one activity for ten minutes. After each condition, participants reported their heart rate on the worksheet and filled out the post-condition surveys, including questions of player experience, affective state, and the Borg Rating of Perceived Exertion (RPE) [2]. After five minutes of recovery time, participants completed the d2 test. At the end of each condition, volunteers collected the surveys and d2 test sheets. When all groups from both morning and afternoon sessions had finished all the conditions, students returned to the lecture theatre and filled out the post-experiment surveys, including questions on exercise attitude and affective state.

After five months, the same group of children returned to the university for a follow-up survey and to learn about the results of the study. We prepared a 10-minute presentation about the activity exertion levels, survey results and results of the d2 test. They then filled out another exercise attitude survey (5 month follow-up survey) to investigate long-term effects of the intervention on exercise attitudes.

## **Measures**

Exertion was measured through heart rate and the Borg Rating of Perceived Exertion (RPE) [2]. Player experience was collected through Likert scale questions about how fun, exciting, challenging, easy to learn, and frustrating the game was to play. To measure affective state, we used the Self-Assessment Manikin (SAM) scale [3], a pictorial 9-point scale that is used to self-report affective states via valence (feelings of pleasure or displeasure) and arousal (activation of feeling).

To measure cognitive performance, we used the d2 Test of Attention, which measures processing speed, rule compliance, quality of performance, estimated attention and concentration [4]. The test items consist of the letters d and p arranged in 14 lines of 47 characters. The letters have one to four dashes, arranged either individually or in pairs above and below the letter. Subjects are required to cross out any letter 'd' with two dashes arranged in any combination above or below the 'd'. We allowed participants 20 seconds to complete each line. The test is scored such that five metrics are produced in three

categories, including: 1) Speed – the total number of items processed (TN); 2) Accuracy – the total number of errors (E), and the percentage of errors (E%); and 3) Overall Performance – the total number of items scanned minus error scores (TN-E), and the number of correctly crossed out relevant items minus the errors of commission (CP). TN-E and CP are indicators of concentration.

## **Apparatus**

We arranged two computer labs at a local university to run the experiment. Both the sedentary and exergame conditions were held in the same computer lab with 12 computers available for each condition. The game was played on a Windows PC with a 20-inch widescreen monitor. For the exergame condition, participants stood about 1.2m from the display. The computer labs were arranged like a standard classroom, with rows of desks facing the front of the class.

## **Data Analyses**

Although all participants engaged in all three experimental conditions, the time between each condition did not allow for heart rates to return to resting levels. As such, we treated the experiment as a between-subjects experiment, using data from only the first condition played, for the measures %maxHR, perceived exertion, and the results of the d2 test of attention. A one-way ANOVA was conducted with condition as a factor (exergame, sedentary, exercise), and we used the Tukey HSD test for post-hoc measurements. Questionnaire responses (affective state, player experience, and attitude) were analyzed using the Friedman Test for multiple related samples.

## **Quantitative Results**

### *Physical Exertion*

The American College of Sports Medicine defines moderate-intensity exercise as 64-76% of maximum heart rate ( $\text{maxHR} = 220 - \text{age}$ ) [39], vigorous-intensity exercise as 77-93% of maximum heart rate and very hard intensity exercise as greater than 94 of maximum heart rate. Table 1 shows the average percentage of maximum heart rate (%maxHR) of the participants (split by sex). While the values for the exergame condition are within the range of moderate to vigorous-intensity exercise, heart rates for the exercise condition are within the range of vigorous to very hard-intensity exercise. A one-way ANOVA showed that the differences in %maxHR were significant for both boys and girls ( $F_{2,56} = 150.2$ ,  $p \approx .000$ ; see Table 1). Tukey's test showed that exercise intensity in the sedentary condition was significantly lower than intensity produced in the exergame condition ( $p \approx .000$ ) and exercise condition ( $p \approx .000$ ), and that the exergame condition was significantly lower than the exercise condition ( $p \approx .000$ ). In addition to heart rate information, average Borg Ratings of Perceived Exertion (BorgRPE) were included in our

study (see Table 1), and results are in line with participants' heart rates: The exergame condition produced perceived exertion values within the recommended intensity for improving aerobic capacity: 12-13 (somewhat hard) to 15-16 (hard) [31]. The differences in perceived exertion between conditions were significant ( $F_{2,53}=44.9$ ,  $p\approx.000$ ; see Table 1). Again, pairwise comparisons showed that the sedentary condition produced significantly lower levels of perceived exertion than the exergame condition ( $p\approx.000$ ) and traditional exercise ( $p\approx.000$ ), and that exergame condition was significantly lower than exercise condition ( $p=.001$ ).

	<b>%maxHR</b>	<b>BorgRPE</b>
<i>Resting</i>	41.3(6.2)	N/A
<i>Sedentary</i>	48.6 (8.8)	9(2.6)
<i>Exergame</i>	78.0 (9.1)	13 (1.5)
<i>Exercise</i>	94.0 (6.5)	16 (2.6)

**Table 1. Means and SDs for measures of physical exertion.**

### *Affective Benefits*

Descriptive results for the effects of the different conditions on valence and arousal are displayed in Table 2. Across all three conditions, results for valence were rather high, suggesting a positive mood among participants. A Friedman's Test for 3-related samples showed no significant difference in valence ( $\chi^2_2=3.3$ ,  $p=.195$ ), but there was a significant difference in arousal ( $\chi^2_2=34.3$ ,  $p\approx.000$ ; see Table 2). Pairwise comparisons revealed that players felt more aroused after the exercise condition than after the exergame condition ( $p=.001$ ) or the sedentary condition ( $p\approx.000$ ), and more aroused after the exergame condition than the sedentary condition ( $p=.031$ ).

	<b>Valence</b>	<b>Arousal</b>
<i>Sedentary</i>	6.54 (1.92)	3.59 (2.35)
<i>Exergame</i>	6.78 (1.82)	4.54 (2.22)
<i>Exercise</i>	6.46 (2.08)	6.24 (2.21)

**Table 2. Means and SDs for valence and arousal (1 is low, 9 is high).**

### *Cognitive Benefits*

Table 3 shows the descriptive results of the d2 test of attention. Our values are in the range of the norms for the age groups participating in our study, which are provided by the test authors [4]; however, the average score of concentration (TN-E) across all of our participants and conditions is at the 97<sup>th</sup>



percentile. This suggests that there were some artifacts as a result of the way that the test was administered, which we consider further in the discussion.

A one-way ANOVA, with condition as factor, revealed that there were no significant differences in any of the measures (see Table 3). Although Table 3 shows the expected trends (concentration (CP) worse after sedentary condition than after exergame condition), because of the between-subjects analysis and the way that the test was administered in a group, the subtle differences in attention as a result of exercise were not statistically significant (see Table 3). Interestingly, the trend in Table 3 shows that the exercise condition produced lower levels of concentration than the exergame condition. Although not significant, this trend likely due to the elevated levels of exertion produced by the exercise condition, causing a loss of concentration due to fatigue.

	<b>TN</b>	<b>E</b>	<b>E%</b>	<b>TN-E</b>	<b>CP</b>
<i>Sedentary</i>	433.60 (65.49)	29.25 (26.98)	6.89 (6.71)	404.35 (71.73)	161.55 (37.85)
<i>Exergame</i>	429.17 (57.04)	17.17 (11.48)	4.08 (2.86)	412.00 (58.67)	168.33 (25.79)
<i>Exercise</i>	422.06 (77.23)	39.94 (30.61)	7.6 (7.5)	391.11(85.63)	157.00 (43.67)
<i>F<sub>2,53</sub>, p</i>	.142, .868	1.7, .192	1.7, .191	.380, .686	.438, .648

**Table 3. Mean results and SDs for the d2 test of attention.**

### *Player Experience*

We asked participants to rate six core aspects of the activities (fun, ease of learning, excitement, challenge, frustration, and whether they would consider playing it if they had a 10-minute break) on a 5-point Likert scale. The results show that participants' experience with the mouse and Kinect versions of the game as well as in the traditional exercise condition were generally positive (Table 4). A Friedman test for 3-related samples showed significant differences in the ratings for challenge and easy to learn and marginally-significant differences for fun, excitement, and whether they would consider to play it (see Table 4). Pairwise comparisons using the Wilcoxon Signed Rank Test revealed that participants rated the exergame condition as significantly more fun than the exercise condition ( $p=.045$ ) and would consider playing the exergame in the future rather than engage in traditional exercise ( $p=.008$ ). Results for challenge mirror our findings regarding physical exertion the exercise condition being most challenging, followed by the exergame condition, and the sedentary condition (all differences significant with  $p<.05$ ). The sedentary game was seen as easier to learn than the exergame ( $p=.007$ ) and the exercise

condition ( $p \approx .000$ ). Finally, the exergame condition was rated as more exciting than the sedentary condition ( $p = .005$ ).

	<b>Sedentary</b>	<b>Exergame</b>	<b>Exercise</b>	$\chi^2$	<i>p</i>
<i>Fun</i>	3.85 (1.03)	3.85 (1.13)	3.44 (1.32)	5.8	.055
<i>Easy to learn</i>	4.83 (0.62)	4.60 (0.74)	4.32 (0.94)	19.8	.000
<i>Excitement</i>	3.39 (1.11)	3.78 (1.15)	3.59 (1.23)	6.0	.051
<i>Challenge</i>	2.49 (1.44)	2.88 (1.26)	3.59 (1.42)	24.7	.000
<i>Frustration</i>	1.92 (1.21)	2.13 (1.30)	2.20 (1.20)	3.0	.226
<i>Consider</i>	3.02 (1.38)	3.37 (1.26)	2.83 (1.42)	5.7	.059

**Table 4. Mean results and SDs for player experience ratings.**

### *Exercise Attitude*

In addition to information on player experience, we investigated participants' attitudes about exercise and exergames. We were interested in whether participating in the study would change their attitudes. The following three statements had to be rated on a 5-point Likert scale (1=strongly disagree, 5=strongly agree): (1) I can concentrate better shortly after I exercise; (2) I can concentrate better if I exercise regularly; (3) Playing an exercise game can help me to improve my concentration.

Descriptive results (Table 5) show that participant responses are average, suggesting a neither overly positive nor negative attitude towards exercise.

	<i>Baseline</i>	<i>Post-Experiment</i>	<i>5 months follow-up</i>
<i>Concentration shortly after exercise</i>	3.32 (.88)	3.69 (.81)	2.78 (1.0)
<i>Concentration after exercising regularly</i>	3.65 (.80)	3.71 (.78)	3.14 (1.0)
<i>Concentration shortly after playing exergames</i>	3.37 (.90)	3.45 (.81)	3.04 (1.0)

**Table 5 Means and SDs for survey ratings on a 5-point Likert scale (1=strongly disagree, 5=strongly agree).**

*"I can concentrate better shortly after I exercise."*

A Friedman Test for related samples showed significant differences in the ratings for agreement with this statement at three different times ( $\chi^2_2=18.9$ ,  $p\approx.000$ ). Pairwise comparisons showed that agreement with this statement was significantly lower in 5-month follow-up survey than in the baseline survey ( $p=.042$ ) or the at the end of the day survey ( $p\approx.000$ ). There was no difference between the baseline and end of day surveys ( $p=.118$ ).

*“I concentrate better if I exercise regularly.”*

We found a main effect of agreement with this statement at the three different survey times ( $\chi^2_2=14.8$ ,  $p=.001$ ). Again, pairwise comparisons showed significantly lower agreement with this statement in the 5-month follow-up survey than in the baseline survey ( $p=.014$ ) or the at the end of the day survey ( $p=.006$ ). There was no difference between the baseline and end of day surveys ( $p=.759$ ).

*“Playing an exercise game can help me to improve my concentration.”*

We found a main effect of agreement with this statement at the three different survey times ( $\chi^2_2=8.1$ ,  $p=.018$ ). Again, pairwise comparisons showed that agreement in the 5-month follow-up survey was significantly lower than in the end of day survey ( $p=.047$ ), and marginally lower than in the baseline survey ( $p=.066$ ). There was no difference between the baseline and end of day surveys ( $p=.878$ ).

## **Qualitative Data**

To gain further insights into the potential application of exergames in a classroom setting, at six months post-study, the same group of children provided explanations of their exercise attitudes. The explanation surveys offer insights into students’ opinions regarding the effects of physical activity on their ability to concentrate. Additionally, we invited their teachers to conduct an online survey on their observation of students’ physical activity at school, opinions on students’ physical education in the classroom, and the deployment of exergames.

## **Students’ Attitudes towards Exercise and Exergames**

### *Perceived Short-Term Effects of Exercise on Concentration*

The average rating of the statement *“I can concentrate better shortly after I exercise.”* was 3.28 (on a scale of 1 to 5) ( $SD=.82$ ). Participants were generally able to observe what is going on in their bodies during and shortly after exercise. They gave the reasons such as *“I am happy after I exercise”*, *“It helps get blood flowing to my head”* or *“I feel awake”*. Participants holding negative opinions often mentioned that exercise made them tired, such as *“I am tired after exercising and can't think straight”*. Other reasons included they found exercise makes no difference *“It doesn't really change”* or they forgot what

they were doing before exercise *“Not really because I usually forget what I was doing before exercising sometimes”*. Participants with neutral opinions mentioned that whether short bursts of exercise can improve concentration depended on how hard they exercised, what kind of exercise they did and how much recovery time they were given before they had to work on cognitively challenging tasks: *“It depends how hard I exercise”*, *“Depends on what the exercise is”*, *“If I am tired I can't concentrate so it depends on what I did”* and *“Right after an exercise, you still recovering, so you will concentrate fairly after a exercise”*.

### ***Perceived Long-Term Effects of Exercise on Concentration***

The average rating of *“I concentrate better if I exercise regularly.”* was 3.36 (SD=.69). Many participants agreed with the statement through experience. *“My dancing classes stop usually around June or July. This year they have stopped in May and I am finding it harder and harder to concentrate in my class”*, *“If I exercise half an hour before I need to concentrate I work well”*. The explanation for most participants who held negative options was they did not notice the difference between exercising regularly *“I don't think it makes much of a difference”*. Again, participants with neutral opinions mentioned that the impact of regular exercise on concentration depended on the day, time, and kind of exercise: *“It depends on the exercise and the time of the day”*, *“Usually depends on the day and if I am feeling tired or not”*.

### ***Perceived Effects of Exergames on Concentration***

The average rating for the statement *“Playing an exercise game can help me to improve my concentration.”* at six months post-intervention was 3.5 (SD=.83). Some participants mentioned playing exercise games could give them a break: *“I just “exercise” my brain, gives it a break sometimes”*. Some participants mentioned games are usually fun, can make people compete and help in learning things: *“Exercising will improve your concentration but the game will make you compete more”*, *“Helps me learn things”* and *“They are usually fun and I will continue thinking about it”*. Most participants who held negative views explained they did not notice the difference between playing an exergame or sedentary activities on their ability to concentrate. One participant mentioned he/she prefers other activities: *“I prefer to just play silent ball or something less extravagant”*. Similar to previous statements on the effects of traditional exercise, participants with neutral opinions mentioned that whether an exercise game could improve concentration depended on the type of game and the intensity of physical activity required to engage in play: *“It depends on how much exercising this game gives to me”*.

On a general level, the six-month follow-up explanation surveys showed a range of opinions. Many participants stated that they do believe that exercise can have a positive effect on concentration, while some claimed that they did not notice any effects of exercise on concentration. Those who reported a negative impact of exercise or exergames on concentration frequently stated that it made them feel tired, thus reducing their ability to concentrate and potentially interrupted their workflow. This suggests that students have insight into the effects of physical activity on their ability of participating in cognitively challenging tasks, which needs to be taken into account when designing casual exergames to be played in a classroom setting.

### **Teachers' Perception of Exercise and Exergames**

To gain further insights into activity patterns among high school students and potential changes among teenagers, we investigated teachers' perceptions of physical activity among their students. To assess the potential of exergame deployment in the classroom, we also addressed teachers' opinions on in-class exercise and the application of games.

#### *Age-Related Changes in Physical Activity*

Teachers reported that students are less active during recess times ( $M=2.25$  on a scale of 1 to 5) than students' general physical activity ( $M=3.75$ ), and during class breaks ( $M=3.25$ ). All of the teachers pointed out that students become less active when they grow older. They explained that students want to do their own activities *"Students seem more apathetic toward teacher directed/organized activity. They want to be in charge of their own activity however; unfortunately they still need guidance and motivation"*, and that they are less motivated to exercise: *"less motivated, less interested in getting sweaty, less interested in working hard, slower"*, *"They move less and stop running places. They used to run just because they wanted to get to places as fast as possible. When they get older they slow down and tend to only move fast when playing a game. The worst thing is they seem to require organized sport to motivate them to play hard."* All teachers noticed older students are more sedentary than younger students. They also provided possible explanations for this change: *"longer classes, we expect older ones to sit and work longer - attention span longer"*, *"Body changes, less time because many will start a part time job, more homework in high school, friends"*.

Two teachers mentioned students start to worry about their image, pointing out how *"they become more social and worry about image"*, and that *"other things become more important to them, image!!!!"* Two teachers suggested that girls are more concerned about their image and therefore avoid physical activity: *"They would be just as content to do nothing for fear of how they will be viewed by their peers. This is*

*especially true for girls. I think they refrain from being physical as a result of how they might be perceived”.*

### ***Integration of Physical Activity in the Classroom***

Three out of four teachers report the integration of physical activity into classroom activities, such as cardio, relays, combative, strength, stretch and dance. One teacher said s/he encouraged her/his students to try new activities every day and did body breaks (i.e., brief bouts of exercise) twice a day. When asked whether they noticed whether or not students enjoyed the activities, teachers reported that most students liked it, but some were reluctant to participate. The teacher who frequently integrated physical activity into classrooms pointed out that his/her students *“loved when we counted and did certain jumping activities; they also loved stretching to quiet music”*.

Three out of four teachers claimed positive effects of PE on their students, reporting that they are *“ready to learn, almost energized in a way that they are charged up”*, *“when they really push hard and have fun they seem to come back to class relaxed with less behavioral problems”*, *“I feel they are calmer after they have had a chance to burn off some steam”*. Only one teacher who did not integrate any physical activities in classroom claimed that after PE, students are fidgety, and *“it is difficult to settle them back into the classroom setting”*.

### ***Integration of Exergames in the Classroom***

Three out four teachers would like to integrate casual exergames in the classroom. Teachers expected benefits such as *“increased motivation towards getting physically active”* and *“increased focus”*. Furthermore, they saw advantages such as an *“increased heart rate, increased muscle memory, and motivation to score better than the last time”*. Teachers also noticed potential drawbacks of exergames, such as *“cheating, lack of motivation to those that are jocks”*, and games being distractive, and a *“disruption of others”*.

When asked how they would integrate casual exergames in the classroom, they came up with solutions such as *“setting up a station, whole class approach where one or 2 or 6 people are active and rest of class is holding a pose while they are doing the challenge. Almost like a relay race”*, *“probably as body breaks as the students see as necessary for their own personal wellness”* and *“might need to play it by ear but could set up a rotation or allow sign up to be used by those who enjoy it as a body break”*.

When comparing casual exergames to regular exercise, teachers saw advantages of casual exergames, expecting them to *“increase confidence to those lacking skill in certain areas”*, pointing out that

*“students will have more personal control and responsibility over their body breaks”*. Regarding students’ attitudes towards exercise, teachers pointed out that they *“think it is something the students are more open to. It is an excellent way to disguise exercise”*.

These results show that the teachers who participated in our survey are generally open towards the integration of physical activity in the classroom. Their statements show that they are aware of benefits of activity, but that they also recognize potential problems such as the disruption of other students if exercise units are not well-integrated into the schedule. Furthermore, the results underline the change in students’ attitudes towards physical activity at the transition from childhood to adolescence, particularly highlighting sedentary lifestyles among girls. The results of the survey show that teachers are willing to integrate exergames in the classroom, but that additional challenges need to be overcome to provide technologies that respect school routines and address the special requirements of the classroom as a design space.

## **DISCUSSION**

### **Contributions and Findings**

Our results show that the exercise and exergame condition both provided intense workouts. The exergame condition demonstrated moderate to vigorous exertion, and the exercise condition created workouts at near maximum intensity, both in terms of objectively-measured heart rate and subjectively measured exertion. The similarities in heart rate and ratings of perceived exertion show that students were able to rate the intensity at which they exercised, suggesting that they understood the physiological signals of exertion, and were able to subjectively evaluate exercise intensity. This is an important insight for exergame design: if students can accurately self-rate exercise intensity, then self-paced exergames can tailor the physical challenge necessary to produce optimal levels of exertion for health benefits and player engagement. The also results show that exertion levels in the exercise condition were very high, exhausting students physically after only 10 minutes of play, which the students felt affected their ability to concentrate. Students commented that when they felt exhausted from physical activity, they couldn’t concentrate.

The results of the cognitive test showed this same trend (performance improved with increases in heart rate, but then decreased once exertion levels were too high), although these differences were not statistically significant. We were unable to confirm prior findings that suggested casual exergames have

acute cognitive benefits [12] compared with the same game played sedentarily. In our study, participants completed the d2 as a group, without the benefit of one-on-one supervision. It was difficult to ensure that participants completed the test correctly, for example, making sure that they moved onto the next line after 20 seconds, and ensuring that they did not continue the test once time had expired but prior to test collection. Although our participants were from a privileged background and an excellent educational institution, the relatively high scores of the participants in general (average of concentration (TN-E) over all participants and conditions at 97<sup>th</sup> percentile as compared to norm values for children of this age [4]) suggest that there may have been difficulties in the administration of the d2 tests. Implementing a computerized version of a test of attention would provide more accurate results in future studies, which might then yield significant differences in concentration as a result of exercise. The acute benefits shown in previous work [12] were small effects – the exergame represented a 14.2% improvement in performance over the sedentary game – but they were significant. Thus, it will be important to deploy accurate testing to confirm these effects in a population of schoolchildren. It is also worth noting that the improvements reported in [12] were found in a laboratory setting in a controlled environment. In the less structured environment described in this experiment and in a classroom deployment, the small but statistically significant acute cognitive benefits might be overwhelmed by the distractors and episodes of everyday life.

The results of the player experience survey showed that students had more fun playing the exergame than doing traditional exercise. Moreover, students would consider playing an exergame during a break more than they would consider doing traditional exercise. In general, our participants rated traditional exercise as a fun activity as our sample consists of children who are generally fond of exercise, and the PE teacher made the exercise session fun and motivating (e.g., by playing loud music, shouting encouragement, participating with the children, and using props like rope ladders). However, it is a promising result that the students enjoyed the exergame more than traditional exercise and indicated they would play the exergame more than traditional exercise if they had 10-minutes of free time in a day, such as in breaks between classes.

Our results show that our participants' exercise attitudes were slightly above neutral when they were asked about the impact of exercise on concentration; this did not change at the end of their participation in the experiment. Interestingly, we found that the children's attitudes about the impact of exercise on concentration dropped significantly after being shown the results of their study, even though the charts clearly suggested the benefits of exercise (the y-axis scale was set to the range of the results, which



suggested differences between the conditions). In the follow-up session, students explained that they expected their concentration scores to drop after traditional exercise, as they were too tired to concentrate well. Yet their answers for whether an exergame could help them concentrate also dropped in this follow-up session. Their verbal explanations for their ratings suggested that they may have been conflating the concepts of teacher-prescribed exercise and self-paced exergames and the relative effects that these two activities have on concentration. Their comments do, however, demonstrate that they understand that there are physical and cognitive benefits of exercise and that there is complexity in how the cognitive benefits occur.

The teachers' observations about their students' physical activities at school provided valuable opinions both on the nature of exercise in pre-adolescence and on the potential for casual exergames to help improve physical activity among schoolchildren. The teachers noted that students become more sedentary, less motivated and less interested in exercise when they grow older and most teachers already integrate physical activities into classroom activities, such as stretches and dance, to help students reenergize between class breaks. Teachers also noted that students enjoy short chunks of physical activity, which anecdotally seems to have positive effect on concentration. Similarly, teachers found that after PE class, students were often charged up and ready to learn.

### **The Deployment of Casual Exergames in Schools**

The goal of our work was to explore how casual exergames can be deployed in schools to give kids the physical activity they require, and the cognitive advantages that result. Contrary to earlier work [15] our findings demonstrated that self-paced exergames can produce exertion levels in the children that meet current guidelines of physical activity.

The students' explanations of their attitudes demonstrated that they understand the cognitive advantages of exercise, and that they felt that too much exertion without sufficient time for recovery negatively affected their ability to concentrate. Some of the students mentioned that this problem could be addressed in the deployment of casual exergames, such as allowing students to pick the times when they wanted to participate, or in the design of casual exergames, by having the games ensure an intensity level within recommended guidelines. The latter approach could involve incorporating heart rate data into the game to adapt game challenges or dynamically balance game variables [33]. However, our causal exergame produced exertion levels within the recommended guidelines, suggesting that the students paced themselves effectively. The teacher-prescribed exercise was perhaps too intense for cognitive benefits; however, students were able to achieve the appropriate level of exertion when

playing GrabApple, showing that a well-designed casual exergame could help students self-pace for both physical and cognitive benefits.

Teachers were also interested in integrating casual games in the classroom to increase students' physical health and increase their focus after playing such games. Teachers noted that casual exergames have advantages over exercise by allowing students to have more control and being able to track students' physical activities individually. From teachers' feedback, we know those interviewed are positive and supportive in deploying casual exergames in classrooms. Moreover, teachers provided practical concerns, such as lack of space, disruption of others and cheating when playing the game. For example, classroom space varies among schools, so the location of an exergame system within the school (e.g. in a classroom or common area) must be addressed on a case-by-case basis. Teachers noted that students might cheat during play, so exergames should be robust enough to prevent students from gaming the input device or game mechanic. Finally, teachers reported different ideas on how exergames might be integrated into the classroom, such as letting students take turns like a relay race, letting interested students sign up, or using these games as a reward.

### **Limitations and Future Work**

Our results show the potential possibilities of casual exergame deployment at schools; however, there are limitations in what we can infer from our studies and new research opportunities that have been created as a result of our work.

Our participants may not be representative of the general population of pre-adolescent schoolchildren. They come from a privileged neighbourhood, are generally high achieving, and are in a pilot educational program on staying healthy, so they hold positive attitudes towards exercise. Our results may not extend to children who are physically inactive or who have poor attitudes about exercise, and it will be of importance to determine how a less active population of schoolchildren responds to casual exergames.

The students in our study played the casual exergame for only ten minutes and the novelty of the Kinect-based game may have affected the players' perceptions its fun. Outside of the context of our study, we do not know how motivated people would be to play a casual exergame over the long term. Our study is the first step to investigate the potential of casual exergames in schools; the next logical step will be to development of casual exergame design guidelines for classroom use and deploy a suite of casual exergames in a classroom as a longitudinal study to determine the long-term efficacy of casual exergames as a pre-adolescent school-mediated health intervention.

Our work used a single casual exergame in an experimental setting. It would be worthwhile to investigate the inclusion of other motivational elements, such as leader boards, classroom competition, or cooperative multiplayer games in a social context [21]. However, social motivation can work both ways, so games need to be carefully designed so that less active children do not start out at a disadvantage, and are thus demotivated to play [33].

Finally, the ultimate goal is to use casual exergames as a way to promote exercise so that schoolchildren experience the benefits sufficiently to continue to exercise on their own outside of the context of exergames in school. Creating systems that work both within and outside of the school environment will be important to help adolescents continue to get sufficient physical activity, as will games that incorporate real-world activity into the gameplay [34,35].

## **CONCLUSION**

Although the importance of physical activity and its positive effects on learning processes are widely known, schools struggle to provide sufficient opportunities for physical activity to their students. This effect is particularly apparent as students transition from childhood to adolescence. Casual exergames may be a means of encouraging physical activity amongst pre-adolescents. Due to the special characteristics of these games (interruptible, short chunks of play, easy setup routines), they are well suited for deployment in schools for play during natural breaks in the school day, such as at lunch or recess. We have demonstrated that students see the benefits of moderate physical activity throughout the day, and that they enjoy engaging with our casual exergame GrabApple, as a preferable alternative to traditional exercise. Casual exergames can also be applied to help people regain focus during crucial periods of their day and yield acute cognitive benefits. Students demonstrated a mature understanding of the relationship between cognition and activity level, implying that self-regulated casual exergames could be employed in a school environment. Further evidence of the utility of casual exergames in a school environment was provided by teachers who noted several methods where exergames could be successfully deployed in a classroom setting. This work in aggregate makes a strong case for the utility of casual exergames in a classroom setting.

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## CHAPTER 5

# 5 CONCLUSIONS & FUTURE WORK

### 5.1 SUMMARY

In this thesis, we presented a new genre of game called casual exergames and established its potential physical and acute cognitive benefits through short bursts of play.

In chapter 2, we presented a new genre of games called casual exergames that we define as exergames that are designed to motivate people to exercise in small chunks of time multiple times throughout the day. In general, exergames are fun to play but it was unclear whether exergames could provide enough exertion to meet the current fitness guidelines. In chapter 2, we specifically designed a casual exergame to be played at the moderate intensity exercise level. Also, as casual exergames motivate people to exercise for multiple short bursts throughout the day, we emphasized that casual exergames should be easy to learn and quick to access. Based on our casual exergame definition, we designed and implemented a casual exergame called GrabApple.

Chapter 2 had three important findings: 1), we have applied the design of casual games to the design of exergames and came up with a new genre of casual exergames; 2), based on the definition, we designed and implemented a casual exergame called GrabApple; and 3), through the user study, we showed participants' heart rate was elevated to an average of 72% of maximum heart rate, and burned an average of 91.8 Calories for 10 minutes of play, which produced sufficient physical activity to meet the current fitness guidelines.

From chapter 2, we knew that playing casual exergame for only 10 minutes can produce sufficient exertion levels, and we also know that research has already shown that short duration exercise can produce acute cognitive benefits, such as improved concentration. These acute benefits do not indicate an improved ability (i.e., changes in actual brain structure), but increase in concentration that can help people better focus on their work and improve their performance to better demonstrate their existing abilities. What remained unclear was whether short durations

of casual exergame play could result in acute improvements in cognition. We did not know whether the benefits produced are as pronounced as those produced by performing traditional exercise activities, such as running. To answer these questions, we conducted two studies to compare playing 10 minutes of our casual exergame to a sedentary version of the game or exercise on a treadmill.

In Chapter 3, we had four main contributions: 1), we found that 10 minutes of casual exergame play can produce similar exertion levels to running on a treadmill and significantly higher levels than playing a sedentary casual game; 2), we found that 10 minutes of casual exergame play can improve performance on cognitive tests that measure concentration, compared to a sedentary version of the casual game; 3), we found that players reported having more fun playing the casual exergame than exercising on a treadmill exercise; and 4), we found that participants reported improved affective states after casual exergame play.

After demonstrating the physical exertion levels of and acute cognitive benefits after playing causal exergames for short periods of time, in Chapter 4, we examined the feasibility of casual exergame deployment at school to help children especially teenagers fight with their sedentary tendencies during their transition from childhood to adolescence. To examine this, we did an experiment with 75 elementary school students and asked their attitudes on the impact of exercise on concentration. Also, we gathered teachers' opinions on physical education and casual exergame deployment in classroom settings.

There were two main contributions in Chapter 4: 1), we showed that casual exergames can be deployed in a classroom-like setting, yielding effects similar to those shown in lab studies; 2), we gathered students' and teachers' attitudes towards exercise and exergames in a school setting and provide an overview of their opinions as a basis for future work.

Throughout chapters 2, 3 and 4, we have shown that casual exergames have the potential to help adults and children to get their recommended amount of exercise throughout the day and also provide acute cognitive benefits in an enjoyable way.



## **5.2 FUTURE WORK**

Despite the significant contribution of our research results, there remain issues that should be addressed by future work. In addition, our research has opened opportunities for future work addressing casual exergames for wellness.

### **5.2.1 Establish Cognitive Improvements through Direct Measurements**

In Chapter 3, the cognitive improvements we found were measured through outcomes, i.e., standard cognitive tests. Our study results showed people were better able to concentrate, improving their performance on the cognitive tests. We did not establish cognitive improvements through direct measurements, such as using neuroimaging techniques to examine the level of focus exhibited from post-play. In the future, we would further explore acute cognitive benefits using direct measurements.

### **5.2.2 Long-Term Cognitive Benefits**

In chapter 3, the measured cognitive benefits were short and temporary. In this thesis, we did not examine whether repeated casual exergame play over the long term can result in general cognitive benefits. In the future, we can investigate the long-term cognitive benefits through a long-term field study. For example, long-term casual exergame play may improve people's cognition, which can benefit special populations such as children with fetal alcohol spectrum disorder – which is generally co-diagnosed with attention deficit hyperactivity disorder.

### **5.2.3 Real World Casual Exergame Deployment**

In Chapter 4, we demonstrated students enjoyed playing our casual exergame, regarding it as a preferable alternative to traditional exercise and based on our study feedback. However, for a long term, we still do not know how motivated students would be to play casual exergames repeatedly throughout the day. In the future, based on our current findings, we plan to deploy our suite of causal exergames at school so children can use casual exergames to refocus and reenergize at their recess time or class breaks. Through a combination of data logging and exit

interviews, we can establish how well the casual exergame motivated children to exercise in small bursts throughout their day.

### **5.3 CONCLUSIONS**

In this thesis, we proposed that playing a casual exergame could be a fun way to help people get their recommended exercise throughout the day. Besides the physical benefits of causal exergame play, people also could gain the acute cognitive benefits, which would better demonstrate their existing abilities. It is clear that casual exergames are still at exploratory stage, but we are encouraged by our results and we believe that by integrating new activity sensors into technology, casual exergames will become more convenient and more accessible to play; therefore, casual exergames may be used to encourage both adults and children to become more active and thus obtain both the physical and cognitive benefits of exercise in a fun and motivating way.

## APPENDIX A

### 6 EXPERIMENTAL MATERIAL STUDY 1

## 6.1 CONSENT FORM STUDY 1

**DEPARTMENT OF COMPUTER SCIENCE  
UNIVERSITY OF SASKATCHEWAN  
INFORMED CONSENT FORM**



Research Project: Grab Apple Casual Exergame Study  
Investigators: Yue Gao, Department of Computer Science (966-2327)  
Dr. Regan Mandryk, Department of Computer Science (966-4888)

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

This study is to find out whether participants enjoy playing casual exergame in short bouts of time compared with a mouse-based casual game.

The study will run in two consecutive days and each day will take approximately 30 minutes, during each day you will play a game and complete either reading comprehension or math test. On the last day, you will be asked to fill out a questionnaire about basic demographic information and the comparison of the two casual games. More details about each task will be given to you by the study supervisor.

At the end of the first day, you will be asked to try to take similar amount of food, caffeine the next day before you come.

The data collected from this study will be used in articles for publication in journals, theses, and conference proceedings.

As one way of thanking you for your time, we will be pleased to make available to you a summary of the results of this study once they have been compiled (usually within two months). This summary will outline the research and discuss our findings and recommendations. This summary will be available on the HCI lab's website: <http://www.hci.usask.ca/>

All personal and identifying data will be kept confidential. No textual excerpts, photographs, or video recordings will be used in the dissemination of research results in scholarly journals or at scholarly conferences. Anonymity will be preserved by using pseudonyms in any presentation of textual data in journals or at conferences. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance with University policy for 5 years post publication. If you have any questions about this aspect of the study, please feel free to ask the study supervisor.

**You are free to withdraw from the study at any time without penalty and without losing any advertised benefits.** Withdrawal from the study will not affect your academic status or your access to services at the university. If you withdraw, your data will be deleted from the study and destroyed.

Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact:

- Dr. Regan Mandryk, Dept. of Computer Science, (306) 966-4888, [regan@cs.usask.ca](mailto:regan@cs.usask.ca)

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. If you have further questions about this study or your rights as a participant, please contact:

- Dr. Regan Mandryk, Professor, Dept. of Computer Science, (306) 966-4888, [regan@cs.usask.ca](mailto:regan@cs.usask.ca)
- Office of Research Services, University of Saskatchewan, (306) 966-4053

Participant's signature: \_\_\_\_\_

Date: \_\_\_\_\_

Investigator's signature: \_\_\_\_\_

Date: \_\_\_\_\_

A copy of this consent form has been given to you to keep for your records and reference. This research has the ethical approval of the Office of Research Services at the University of Saskatchewan.

## 6.2 DEMOGRAPHIC SURVEY STUDY 1

\* Required

Participant ID \*

Age \*

Gender \*

- ☐ Female  
☐ Male

How often (on average) do you play games? \*

- ☐ Every day  
☐ A few times per week  
☐ Once per week  
☐ A few times per month  
☐ Once per month  
☐ A few times per year  
☐ Once per year or less

What are your favorite game genres? (You can choose more than one answer) \*

- ☐ First-Person Shooters  
☐ Third-Person Shooters  
☐ Fighting  
☐ Real-time Strategy  
☐ Turn-based Strategy  
☐ Role-playing games  
☐ Adventure games  
☐ Action-adventures  
☐ Racing games  
☐ Sports  
☐ Simulation

- ☐ Party games
- ☐ Music games
- ☐ Casual games
- ☐ Puzzle games
- ☐ Digital board games
- ☐ Serious games
- ☐ Other:

Rate your previous experience with the Microsoft Kinect games. \*

	1	2	3	4	5	
No experience	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Often play

How often do you get 30 minutes of sustained physical activity? \*

- ☐ More than once per day
- ☐ Once per day
- ☐ 4-6 times per week
- ☐ 2-3 times per week
- ☐ Once per week
- ☐ Less than once per week
- ☐ Other:

In total, how many minutes per day do you exercise on an average day?(Exercise means you have an elevated heart rate) \*

- ☐ More than 60 minutes
- ☐ 30-60 minutes
- ☐ 15-30 minutes
- ☐ 0-15 minutes
- ☐ 0 minutes
- ☐ Other:

I want to do regular exercise but it is hard for me to work out regularly.If you do exercise regularly, please skip this question.

	Strongly disagree	Disagree	Medium agree	Agree	Strongly agree
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	Strongly disagree	Disagree	Medium agree	Agree	Strongly agree
Reason: no time	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reason: lazy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What kind of exercise do you normally do? (You can choose more than one answer) \*

- ☐ Yoga
- ☐ Play sports
- ☐ Jogging
- ☐ Swimming
- ☐ Running
- ☐ Cycling
- ☐ Dancing
- ☐ Ice-skating
- ☐ Treadmills
- ☐ Anaerobic exercise, such as sit-ups, pull-ups and push-ups, squats and weight lifting
- ☐ Other:

How often do you take a short break (e.g. coffee break or walking) when you are at work? \*

- ☐ Every half hour
- ☐ Every hour
- ☐ Every 1-2 hours
- ☐ Seldom
- ☐ Other:

### 6.3 POST PLAY SURVEY STUDY 1

Answer the questions below. \*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Mouse version is fun to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Kinect version is fun to paly	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mouse version is exciting to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Kinect version is exciting to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mouse version is challenging to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Kinect version is challenging to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mouse version is frustrating to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Kinect version is frustrating to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mouse version is easy to learn to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Kinect version is easy to learn to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mouse version is difficult to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Kinect version is difficult to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



If I have a casual exergame available, I will consider playing the casual exergames when I have ten-minute free time in a day, such as my break time during work and lunch break.\*

	1	2	3	4	5	
Strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly agree

Do you have some general opinions about the two casual games?



Do you have any other comments about the experiment itself?

[illegible]

## APPENDIX B

### 7 EXPERIMENTAL MATERIAL STUDY 2

## 7.1 CONSENT FORM STUDY 2

### 7.1.1 Consent Form Study 2 Part 1

**DEPARTMENT OF COMPUTER SCIENCE  
UNIVERSITY OF SASKATCHEWAN  
INFORMED CONSENT FORM**



Research Project: GrabApple Casual Exergame Study Part 2  
Investigators: Yue Gao, Department of Computer Science (966-2327)  
Dr. Regan Mandryk, Department of Computer Science (966-4888)

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

This study is to find out whether participants enjoy playing casual exergame in short bouts of time compared with a mouse-based casual game and exercise on a treadmill for ten minutes.

You will come to the lab for four sessions, held at the same time of day, within one week of each other and on each day it will take approximately 20 to 30 minutes. On the first day, you will have a training section on both casual games and treadmill exercise. Also, you will fill out a demographics questionnaire and PAR-Q questionnaire. During each day, you will first fill out a Self-Assessment-Manikin Scales, and then you will play a game or exercise for 10 minutes, and fill out a post questionnaire, a Borg Rating of Perceived Exertion, a Self-Assessment-Manikin Scales and a cognitive test afterwards. On the last day of the study, you will be asked to fill out a general questionnaire about the study. More details about each task will be given to you by the study supervisor.

For the last three days, you will come to the lab at the same time on each day to avoid confounding factors associated with circadian variation. You will be asked not to engage in any structured exercise on the day of your testing sessions and will be asked not to smoke or consume caffeine for three hours prior to the session.

The data collected from this study will be used in articles for publication in journals, theses, and conference proceedings.

As one way of thanking you for your time, we will be pleased to make available to you a summary of the results of this study once they have been compiled (usually within two months). This summary will outline the research and discuss our findings and recommendations. This summary will be available on the HCI lab's website: <http://www.hci.usask.ca/>

All personal and identifying data will be kept confidential. No textual excerpts, photographs, or video recordings will be used in the dissemination of research results in scholarly journals or at scholarly conferences. Anonymity will be preserved by using pseudonyms in any presentation of textual data in journals or at conferences. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance with University policy for 5 years post publication. If you have any questions about this aspect of the study, please feel free to ask the study supervisor.

**You are free to withdraw from the study at any time without penalty and without losing any advertised benefits.** Withdrawal from the study will not affect your academic status or your access to services at the university. If you withdraw, your data will be deleted from the study and destroyed.

Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact:

- Dr. Regan Mandryk, Dept. of Computer Science, (306) 966-4888, [regan@cs.usask.ca](mailto:regan@cs.usask.ca)

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. If you have further questions about this study or your rights as a participant, please contact:

- Dr. Regan Mandryk, Professor, Dept. of Computer Science, (306) 966-4888, [regan@cs.usask.ca](mailto:regan@cs.usask.ca)
- Office of Research Services, University of Saskatchewan, (306) 966-4053

Participant's signature: \_\_\_\_\_

Date: \_\_\_\_\_

Investigator's signature: \_\_\_\_\_

Date: \_\_\_\_\_

A copy of this consent form has been given to you to keep for your records and reference. This research has the ethical approval of the Office of Research Services at the University of Saskatchewan.

## 7.1.2 Consent Form Study 2 Part 2

### DEPARTMENT OF COMPUTER SCIENCE UNIVERSITY OF SASKATCHEWAN INFORMED CONSENT FORM



Research Project: Grab Apple Casual Exergame Study Part2  
Investigators: Yue Gao, Department of Computer Science (966-2327)  
Dr. Regan Mandryk, Department of Computer Science (966-4888)

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

This study is to find out whether short time casual exergames have cognitive benefits compared with a mouse-based casual game. You will come to the lab for two sessions, held at the same time of day and on each day it will take approximately 45 to 50 minutes. On the first day, you will have a training session on both casual games. Also, you will fill out a demographics questionnaire and PAR-Q questionnaire. On both days, you will fill out a Self-Assessment-Manikin Scales, and you will play a game for 10 minutes and fill out a post questionnaire, a Borg Rating of Perceived Exertion, a Self-Assessment-Manikin Scales and two cognitive tests afterwards. On the second day of the study, you will be asked to fill out a general questionnaire about the study. More details about each task will be given to you by the study supervisor.

For the two days, you will come to the lab at the same time on each day to avoid confounding factors associated with circadian variation. You will be asked not to engage in any structured exercise on the day of your testing sessions and will be asked not to smoke or consume caffeine for three hours prior to the session.

The data collected from this study will be used in articles for publication in journals, theses, and conference proceedings.

As one way of thanking you for your time, we will be pleased to make available to you a summary of the results of this study once they have been compiled (usually within two months). This summary will outline the research and discuss our findings and recommendations. This summary will be available on the HCI lab's website: <http://www.hci.usask.ca/>

All personal and identifying data will be kept confidential. No textual excerpts, photographs, or video recordings will be used in the dissemination of research results in scholarly journals or at scholarly conferences. Anonymity will be preserved by using pseudonyms in any presentation of textual data in journals or at conferences. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance with University policy for 5 years post publication. If you have any questions about this aspect of the study, please feel free to ask the study supervisor.

**You are free to withdraw from the study at any time without penalty and without losing any advertised benefits.** Withdrawal from the study will not affect your academic status or your access to services at the university. If you withdraw, your data will be deleted from the study and destroyed.

Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact:

- Dr. Regan Mandryk, Dept. of Computer Science, (306) 966-4888, [regan@cs.usask.ca](mailto:regan@cs.usask.ca)

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. If you have further questions about this study or your rights as a participant, please contact:

- Dr. Regan Mandryk, Professor, Dept. of Computer Science, (306) 966-4888, [regan@cs.usask.ca](mailto:regan@cs.usask.ca)
- Office of Research Services, University of Saskatchewan, (306) 966-4053

Participant's signature: \_\_\_\_\_

Date: \_\_\_\_\_

Investigator's signature: \_\_\_\_\_

Date: \_\_\_\_\_

A copy of this consent form has been given to you to keep for your records and reference. This research has the ethical approval of the Office of Research Services at the University of Saskatchewan.

## 7.2 PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q) STUDY 2 PART 1 & 2

Physical Activity Readiness  
Questionnaire - PAR-Q  
(revised 2002)

# PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
<input type="checkbox"/>	<input type="checkbox"/>	1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
<input type="checkbox"/>	<input type="checkbox"/>	2. Do you feel pain in your chest when you do physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	3. In the past month, have you had chest pain when you were not doing physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
<input type="checkbox"/>	<input type="checkbox"/>	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
<input type="checkbox"/>	<input type="checkbox"/>	7. Do you know of <u>any other reason</u> why you should not do physical activity?

If  
you  
answered

### YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

### NO to all questions

- If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:
- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
  - take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

#### DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

**PLEASE NOTE:** If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

**Informed Use of the PAR-Q:** The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

**No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.**

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME \_\_\_\_\_

SIGNATURE \_\_\_\_\_

DATE \_\_\_\_\_

SIGNATURE OF PARENT  
or GUARDIAN (for participants under the age of majority) \_\_\_\_\_

WITNESS \_\_\_\_\_

**Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.**



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continued on other side...

## 7.3 DEMOGRAPHIC SURVEY STUDY 2

### 7.3.1 Demographic Survey Study 2 Part 1

\* Required

Participant ID \*Please ask the experimenter for your Participant ID.

Age \*

Gender \*

- ☒ Female  
☐ Male

How often (on average) do you play games? \*

- ☐ Every day  
☐ A few times per week  
☐ Once per week  
☐ A few times per month  
☐ Once per month  
☐ A few times per year  
☐ Once per year or less

What are your favorite video game genres? (You can choose more than one answer) \*

- ☐ First-Person Shooters  
☐ Third-Person Shooters  
☐ Fighting  
☐ Real-time Strategy  
☐ Turn-based Strategy  
☐ Role-playing games  
☐ Adventure games  
☐ Action-adventures  
☐ Racing games

- ☐ Sports
- ☐ Simulation
- ☐ Party games
- ☐ Music games
- ☐ Casual games
- ☐ Puzzle games
- ☐ Digital board games
- ☐ Exercise games
- ☐ Other:

Rate your previous experience with Microsoft Kinect games. \*

	1	2	3	4	5	
No experience	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Lots of experience

How often do you get 30 minutes of sustained physical activity? \*

- ☐ More than once per day
- ☐ Once per day
- ☐ 4-6 times per week
- ☐ 2-3 times per week
- ☐ Once per week
- ☐ Less than once per week
- ☐ Other:

In total, how many minutes per day do you exercise on an average day?(Exercise means you have an elevated heart rate) \*

- ☐ More than 60 minutes
- ☐ 30-60 minutes
- ☐ 15-30 minutes
- ☐ 0-15 minutes
- ☐ 0 minutes
- ☐ Other:

I want to do regular exercise but it is hard for me to work out regularly. If you do exercise for 30 minutes at least 3 times per week, please skip this question.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Reason: I'm too busy (no time)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reason: I'm too lazy (no incentive)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reason: I'm too tired from other activities (e.g., work, family)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

What kind of exercise do you normally do? (You can choose more than one answer) If you do not do any exercise, please skip this question

- ☐ Yoga
- ☐ Play sports
- ☐ Jogging
- ☐ Swimming
- ☐ Running
- ☐ Cycling
- ☐ Dancing
- ☐ Ice-skating
- ☐ Treadmills
- ☐ Anaerobic exercise, such as sit-ups, pull-ups and push-ups, squats and weight lifting
- ☐ Other:

How often do you take a short break (e.g. coffee break or walking) when you are at work? \*

- ☐ Every half hour
- ☐ Every hour
- ☐ Every 1-2 hours
- ☐ Seldom



☐ Other:

### 7.3.2 Demographic Survey Study 2 Part 2

\* Required

Participant ID \*Please ask the experimenter for your Participant ID.

Age \*

Gender \*

☐

Female

☐

Male

How often (on average) do you play games? \*

☐

Every day

☐

A few times per week

☐

Once per week

☐

A few times per month

☐

Once per month

☐

A few times per year

☐

Once per year or less

What are your favorite video game genres? (You can choose more than one answer) \*

☐

First-Person Shooters

☐

Third-Person Shooters

☐

Fighting

☐

Real-time Strategy

☐

Turn-based Strategy

☐

Role-playing games

☐

Adventure games

☐

Action-adventures

☐

Racing games

☐

Sports

☐

Simulation

☐

Party games

- ☐ Music games
- ☐ Casual games
- ☐ Puzzle games
- ☐ Digital board games
- ☐ Exercise games
- ☐ Other:

Rate your previous experience with Microsoft Kinect games. \*

	1	2	3	4	5	
No experience	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Lots of experience

How often do you get 30 minutes of sustained physical activity? \*

- ☐ More than once per day
- ☐ Once per day
- ☐ 4-6 times per week
- ☐ 2-3 times per week
- ☐ Once per week
- ☐ Less than once per week
- ☐ Other:

In total, how many minutes per day do you exercise on an average day?(Exercise means you have an elevated heart rate) \*

- ☐ More than 60 minutes
- ☐ 30-60 minutes
- ☐ 15-30 minutes
- ☐ 0-15 minutes
- ☐ 0 minutes
- ☐ Other:

I want to do regular exercise but it is hard for me to work out regularly.If you do exercise for 30 minutes at least 3 times per week, please skip this question.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
--	-------------------	----------	---------	-------	----------------

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Reason: I'm too busy (no time)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reason: I'm too lazy (no incentive)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reason: I'm too tired from other activities (e.g., work, family)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

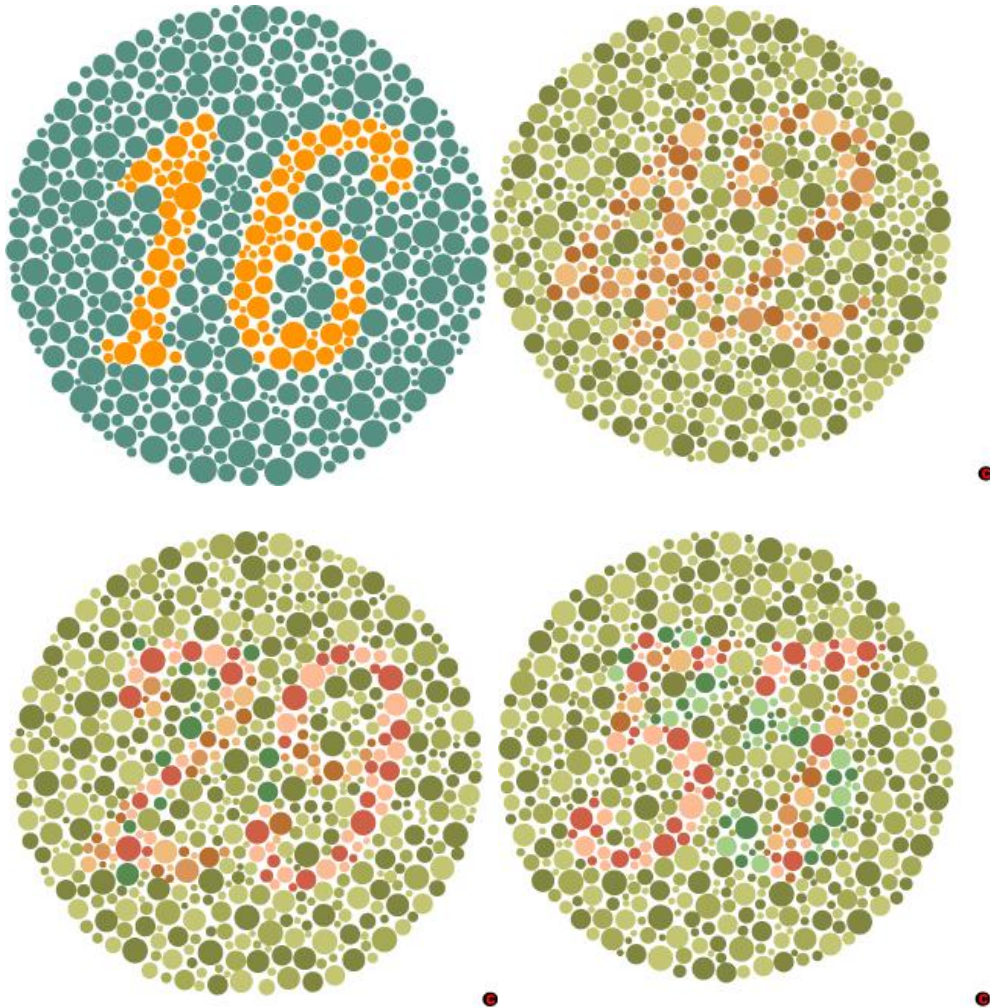
What kind of exercise do you normally do? (You can choose more than one answer) If you do not do any exercise, please skip this question

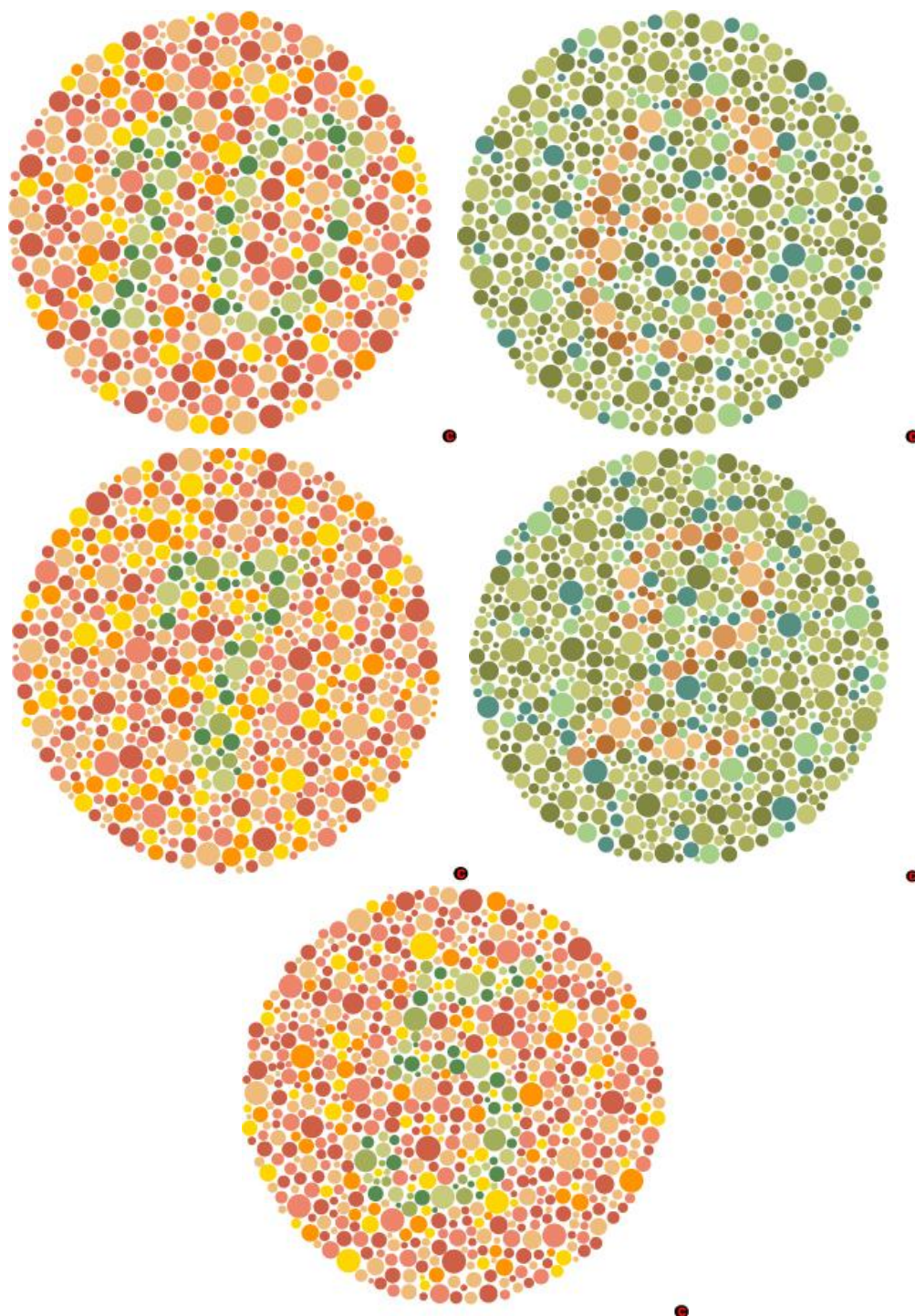
- ☐ Yoga
- ☐ Play sports
- ☐ Jogging
- ☐ Swimming
- ☐ Running
- ☐ Cycling
- ☐ Dancing
- ☐ Ice-skating
- ☐ Treadmills
- ☐ Anaerobic exercise, such as sit-ups, pull-ups and push-ups, squats and weight lifting
- ☐ Other:

How often do you take a short break (e.g. coffee break or walking) when you are at work? \*

- ☐ Every half hour
- ☐ Every hour
- ☐ Every 1-2 hours
- ☒ Seldom
- ☐ Other:

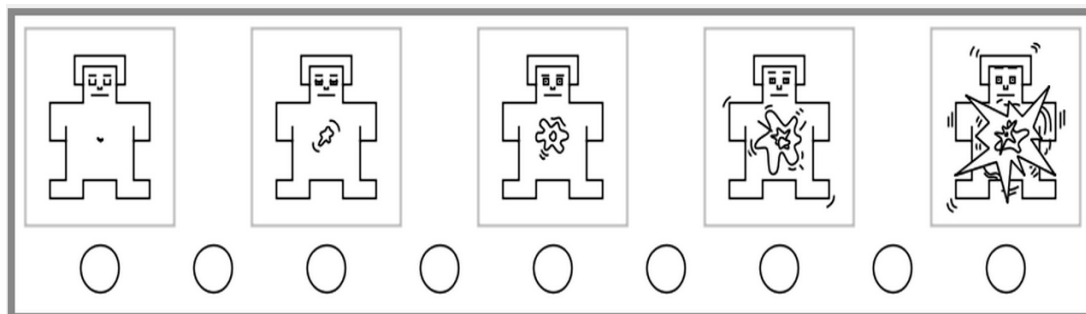
## 7.4 PSEUDOISOCROMATIC PLATE ISHIHARA COMPATIBLE (PIP) STUDY 2 PART 1



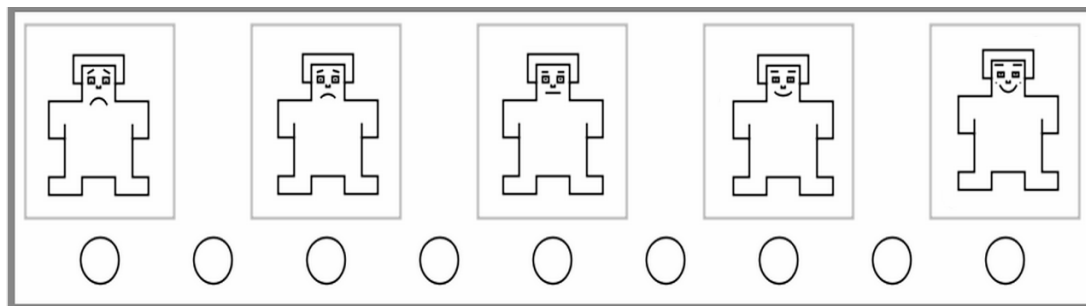


## Self-Assessment-Manikin Scales

1. The scale rates the arousal of your present feeling. At the low end of the arousal scale are feelings like relaxed, calm, sluggish, dull, sleepy, and unaroused. At the high end of the scale are feelings like stimulated, excited, frenzied, jittery, wide awake, and aroused.



2. The scale rates the valence of your present feeling. At the low end of the valence scale are feelings like unhappy, annoyed, unsatisfied, melancholic, despairing, and bored. At the high end are feelings like happy, pleased, satisfied, contented, hopeful, and relaxed.



## 7.6 BORG RATING OF PERCEIVED EXERTION (RPE) STUDY 2 PART1 & 2

While doing physical activity, we want you to rate your perception of exertion. This feeling should reflect how heavy and strenuous the exercise feels to you, combining all sensations and feelings of physical stress, effort, and fatigue. Do not concern yourself with any one factor such as leg pain or shortness of breath, but try to focus on your total feeling of exertion.

Look at the rating scale below while you are engaging in an activity; it ranges from 1 to 15. Choose the number from below that best describes your level of exertion.

4 correspond to "very light" exercise. For a healthy person, it is like walking slowly at his or her own pace for some minutes

8 on the scale is "somewhat hard" exercise, but it still feels OK to continue.

12 "very hard" is very strenuous. A healthy person can still go on, but he or she really has to push him- or herself. It feels very heavy, and the person is very tired.

14 on the scale is an extremely strenuous exercise level. For most people this is the most strenuous exercise they have ever experienced.

1 No exertion at all

2

Extremely light (7.5)

3

4 Very light

5

6 Lights

7

8 Somewhat hard

9



10 Hard (heavy)

11

12 Very hard

13

14 Extremely hard

15 Maximal exertions

## 7.7 POST CONDITION SURVEY STUDY 2

### 7.7.1 Post Condition Survey Study 2 Part 1

#### 7.7.1.1 Post Exercise Survey Study 2 Part 1

\* Required


Participant ID \*

Answer the questions below. \*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
This exercise is fun	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This exercise is exciting	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This exercise is challenging	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This exercise is frustrating	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This exercise is easy to learn to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This exercise is difficult to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

I will consider doing 10-minute exercise when I have ten-minute free time in a day, such as my break time during work and lunch break. \*

Strongly disagree ○ ○ ○ ○ Strongly agree

Submit

### 7.7.1.2 Post Kinect Survey Study 2 Part 1

\* Required

Participant ID \*Please ask the experimenter for your participant ID.

Answer the questions below. \*

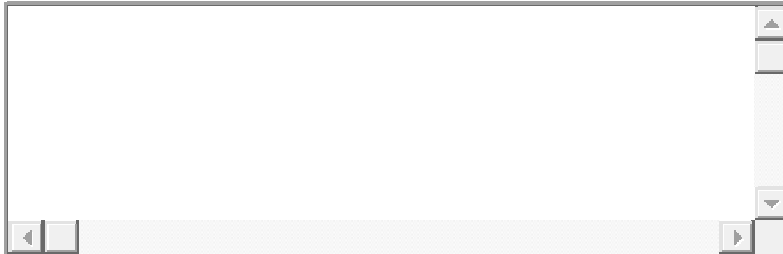
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
This casual exergame is fun to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual exergame is exciting to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual exergame is challenging to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual exergame is frustrating to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual exergame is easy to learn to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual exergame is difficult to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

I will consider playing the casual exergames when I have ten-minute free time in a day, such as my break time during work and lunch break. \*

1      2      3      4      5

Strongly disagree ☐ ☐ ☐ ☐ ☐ Strongly agree

Do you have some general opinions about this casual game?

A large rectangular text input area with a light gray border. It contains no text. On the right side, there are vertical scroll bars with up and down arrows. On the bottom left, there are horizontal scroll bars with left and right arrows.

Submit

### 7.7.1.3 Post Mouse Survey Study 2 Part 1

\* Required

Participant ID \*Please ask the experimenter for your participant ID.

Answer the questions below. \*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
This casual game is fun to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is exciting to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is easy to learn to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is challenging to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is difficult to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is frustrating to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

I would consider playing this casual game when I had ten-minutes of free time in a day, such as a lunch break or work break. \*

1 2 3 4 5

Strongly disagree ☐ ☐ ☐ ☐ ☐ Strongly agree

Do you have some general opinions about the game that you just played?

Submit

## 7.7.2 Post Condition Survey Study 2 Part 2

### 7.7.2.1 Post Kinect Survey Study 2 Part 2

\* Required

Participant ID \*Please ask the experimenter for your participant ID.

Answer the questions below. \*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
This casual game is fun to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is exciting to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is easy to learn to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is challenging to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is difficult to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is frustrating to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

I would consider playing this casual game when I had ten-minutes of free time in a day, such as a lunch break or work break. \*



Strongly disagree ○ ○ ○ ○ Strongly agree

[illegible]

Submit

### 7.7.2.2 Post Mouse Survey Study 2 Part 2

\* Required

Participant ID \*Please ask the experimenter for your participant ID.

Answer the questions below. \*

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
This casual game is fun to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is exciting to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is easy to learn to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is challenging to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is difficult to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
This casual game is frustrating to play	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

I would consider playing this casual game when I had ten-minutes of free time in a day, such as a lunch break or work break. \*

1 2 3 4 5

Strongly disagree ☐ ☐ ☐ ☐ ☐ Strongly agree

Do you have some general opinions about the game that you just played?

Submit

## 7.8 POST EXPERIMENT SURVEY STUDY 2

### 7.8.1 Post Experiment Survey Study 2 Part 1

\* Required

Participant ID \*Please ask the experimenter for your participant ID.

Answer the questions below \*Please rate the three different activities in terms of how much fun they were.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Playing the Mouse version of the game for 10 minutes was fun	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Exercising on the treadmill for 10 minutes was fun	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Playing the Kinect version of the game for 10 minutes was fun	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

If you have 10 minutes available such as a break at work, lunch break, or at home would you consider doing the following activities? \*

- ☐ I would consider playing a casual exergame (such as the Kinect version of GrabApple)
- ☐ I would consider doing exercise (such as walking or climbing stairs)
- ☐ I would consider playing a casual game (such as the Mouse version of GrabApple)
- ☐ Other:

It is recommended that people get 30 minutes of physical activity three times per week. Would you prefer to get this activity by doing sustained activity for 30 minutes, or breaking it into 3 10-minute chunks? \*

- ☐ One chunk of 30 minutes once per day.
- ☐ Three 10-minute chunks per day.

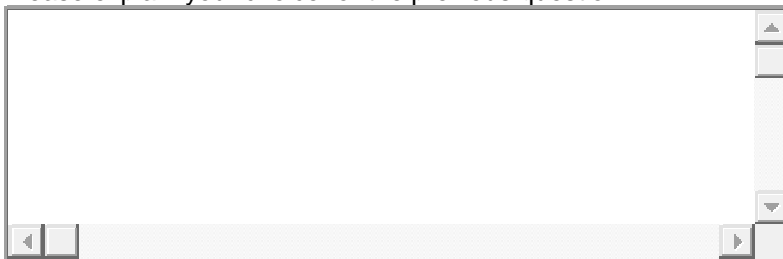
Please explain your choice for the previous question. \*



You completed a cognitive test after each experimental session. Please choose the condition where you felt you performed BEST on that cognitive test. \*

- ☐ Mouse game
- ☐ Kinect game
- ☐ Exercise

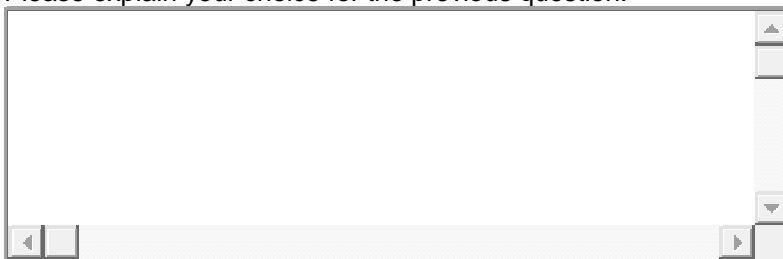
Please explain your choice for the previous question. \*



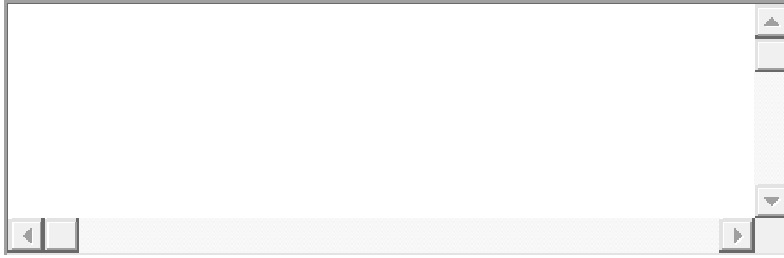
You completed a cognitive test after each experimental session. Please choose the condition where you felt you performed WORST on that cognitive test. \*

- ☐ Mouse game
- ☐ Kinect game
- ☐ Exercise

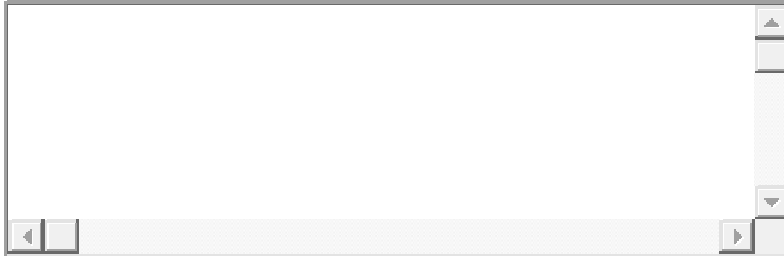
Please explain your choice for the previous question. \*



Do you have some general opinions about the three different 10-minute activities?



Do you have any other comments about the experiment itself?



Submit

## 7.8.2 Post Experiment Survey Study 2 Part 2

\* Required

Participant ID \*Please ask the experimenter for your participant ID.

Answer the questions below \*Please rate the three different activities in terms of how much fun they were.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Playing the Mouse version of the game for 10 minutes was fun	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Playing the Kinect version of the game for 10 minutes was fun	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

If you have 10 minutes available such as a break at work, lunch break, or at home would you consider doing the following activities? \*

- ☐ I would consider playing a casual exergame (such as the Kinect version of GrabApple)
- ☐ I would consider doing exercise (such as walking or climbing stairs)
- ☐ I would consider playing a casual game (such as the Mouse version of GrabApple)
- ☐ Other:

Research shows that 10-minutes of exercise performed 3 times daily has identical benefits to one 30-minute chunk of exercise. Would you prefer to get the 30-minute recommended exercise each day by doing sustained activity for 30 minutes, or breaking it into 3 10-minute chunks? \*

- ☐ One chunk of 30 minutes once per day.
- ☐ Three 10-minute chunks per day.

Please explain your choice for the previous question. \*

You completed a cognitive test where you had to circle symbols after each experimental session. Please choose the condition where you felt you performed BEST on that cognitive test. \*

- ☐ Mouse game
- ☐ Kinect game

Please explain your choice for the previous question. \*

You completed a math test after each experimental session. Please choose the condition where you felt you performed BEST on that math test. \*

- ☒ Mouse game
- ☐ Kinect game

Please explain your choice for the previous question. \*



Do you have any other comments about the experiment itself?



Submit

## **7.9 COGNITIVE TEST STUDY 2**

### **7.9.1 Cognitive Test Study 2 Part 1**

#### **7.9.1.1 Stroop Test Study 2 Part 1**

RED WHITE GREEN BLUE YELLOW  
BLUE RED WHITE YELLOW GREEN  
WHITE RED GREEN YELLOW BLUE  
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YELLOW GREEN WHITE BLUE RED

## APPENDIX C

### 8 EXPERIMENT MATERIAL STUDY 3

## 8.1 CONSENT FORM STUDY 3

### DEPARTMENT OF COMPUTER SCIENCE UNIVERSITY OF SASKATCHEWAN INFORMED CONSENT FORM



Research Project: Physical, cognitive, and affective benefits of exergame play for school children  
Investigators: Prof. Kevin Stanley, Department of Computer Science (966-6747)  
Prof. Regan Mandryk, Department of Computer Science (966-4888)  
Yue Gao, Masters Student, Department of Computer Science  
Kathrin Gerling, PhD Candidate, Department of Computer Science  
Eishita Zibran, PhD Candidate, Department of Computer Science

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

This study is concerned with evaluating the fun, enjoyment, and efficacy of computer games designed to help kids stay active, and their attitudes towards exergames. The goal of the research is to leverage the engagement of video games to encourage kids to be physically active.

Students will come to the university to take part in replicating an actual experiment in the use of casual exergames to both improve fitness and concentration. Students will be split into groups of scientists, computer game players and control. All students will have the opportunity to try all the roles. Students in the scientist group will administer standard tests after each of the exercise groups exercise to determine changes in concentration. Students in the control group will do a standard HBAM challenge exercise regime already done at the school. Students in the game group will play the exergame instead. The game – called GrabApple – is an Xbox Kinect-based game, which uses jumping, sliding and dodging motions to gather virtual apples and put them in a basket. After the experiment students will be asked to fill in a short questionnaire about their experience playing the game, and will be encouraged to give the researchers any feedback. All player data will be anonymized by a random number assigned to each student at the beginning of the session. Only the identity of the school will be revealed in any public dissemination of the results of the study.

This study poses little risk to the students. All data will be strongly anonymized. There is a small physical risk during the activity consistent with a normal physical education class. Students opting out will be provided with an introduction to computer programming session at the university or regular 6-7 split curriculum at their school at the discretion of school staff.

The data collected from this study will be used in articles for publication in journals and conference proceedings.

As one way of thanking you for your participation, we will be pleased to make available to you a summary of the results of this study once they have been compiled (usually within two months). This summary will outline the research and discuss our findings and recommendations. If you would like to receive a copy of this summary, please write down your email address here.

Contact email address: \_\_\_\_\_

All personal and identifying data will be kept confidential. If explicit consent has been given, textual excerpts from the interviews may be used in the dissemination of research results in scholarly journals or at scholarly conferences. Anonymity will be preserved by using pseudonyms in any presentation of textual data. The informed consent form and all research data will be kept in a secure location under confidentiality in accordance with University policy for 5 years post publication.

Your child is free to withdraw from the study at any time without penalty. If they withdraw, their data will be deleted from the study and destroyed. Your right to withdraw data from the study will apply until results have been disseminated. After this it is possible that some form of research dissemination will have occurred and it may not be possible to withdraw all of the data.

After playing the game, students will be asked to fill in a survey requesting basic demographic information and their opinion of the game playing experience, and their overall attitude to exercise. Students will be video recorded while

completing the survey and allowed to provide verbal feedback on the game experience as well as the survey. Participants are free to request the recording be stopped at any time. As such, completing the survey can be construed as a form of focus group. The researcher will undertake to safeguard the confidentiality of the discussion, but cannot guarantee that other members of the group will do so. Please respect the confidentiality of the other members of the group by not disclosing the contents of this discussion outside the group, and be aware that others may not respect your confidentiality.

If you have further questions concerning matters related to this research, please contact Dr. Stanley or Dr. Mandryk.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to allow your child as a participant. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. If you have further questions about this study or your child's rights as a participant, please contact:

- Prof. Kevin Stanley, Department of Computer Science (966-6747), [kstanley@cs.usask.ca](mailto:kstanley@cs.usask.ca)
- Behavioural Research Ethics Board, University of Saskatchewan, (306) 966-2084

**Consent of Parent (to be filled out and brought to school prior to the activity)**

Name of child: \_\_\_\_\_

Name of parent: \_\_\_\_\_

Parent's signature: \_\_\_\_\_

Date: \_\_\_\_\_

**Assent of Student (to be filled out immediately prior to the activity)**

Name of Student: \_\_\_\_\_

Student's signature: \_\_\_\_\_

Teacher's signature (for verbal assent): \_\_\_\_\_

Date: \_\_\_\_\_

A copy of this consent form has been given to you to keep for your records and reference. This research has the ethical approval of the Office of Research Services at the University of Saskatchewan.



## 8.2 DEMOGRAPHIC SURVEY STUDY 3

Name: \_\_\_\_\_

1. Are you – (Check one)

☐ Male

☐ Female

2. How old are you? (Check one)

☐ 9 years

☐ 10 years

☐ 11 years

☐ 12 years

☐ 13 years

3. Do you play computer or video games? (Check one)

☐ YES

☐ NO

How often do you play computer or video games? (Check one)

☐ Almost never

☐ 1 or 2 days a week

☐ 3 or 4 days a week

☐ 5 or 6 days a week

☐ Once a day

☐ More than once a day

4. Do you play games on something that requires physical activity? (Check one) (e.g., Xbox Kinect, Playstation Move, Nintendo Wii)

☐ YES

☐ NO

5. How often do you exercise outside of school (e.g., sports or play) (Check one)?

☐ Almost never

☐ 1 or 2 days a week

☐ 3 or 4 days a week

☐ 5 or 6 days a week

☐ Once a day

☐ More than once a day

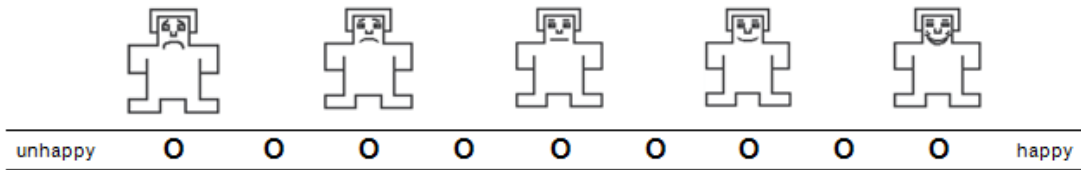
6. How often do you play games on devices that you can hold in your hands (e.g., phone, Sony PSP, Nintendo DS) (Check one)?

- ☐ Almost never
- ☐ 1 or 2 days a week
- ☐ 3 or 4 days a week
- ☐ 5 or 6 days a week
- ☐ Once a day
- ☐ More than once a day

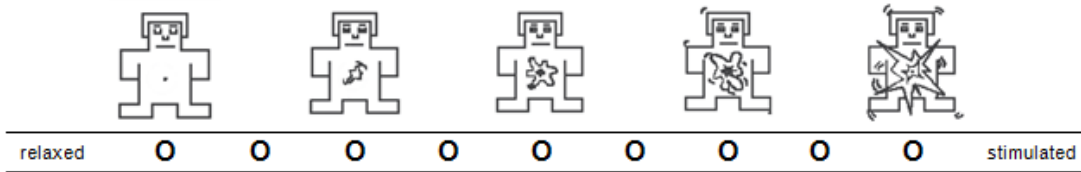
7. Please circle how much you agree with each statement (Circle one):

Healthy bodies make active minds	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I can concentrate better if I exercise regularly	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I concentrate best in the morning	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I concentrate best in the afternoon	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I concentrate best in the evening	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I can concentrate better shortly after I exercise	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Playing an exercise game can help me to improve my concentration	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Regular exercise will not help improve my concentration	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I do not concentrate better shortly after I exercise	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Playing an exercise game will not help me to improve my concentration	Strongly agree	Agree	Neutral	Disagree	Strongly disagree

8. Using the scale presented below, the five graphic figures represent feelings from *unhappy* to *happy*. Please select any of the figures or between any of the figures to express your current feeling.



9. Using the scale presented below, the five graphic figures represent feelings from *relaxed* to *stimulated*. Please select any of the figures or between any of the figures to express your current feeling.



### 8.3 WORK SHEET STUDY 3

Name: \_\_\_\_\_

#### Resting

Resting Heart Rate \_\_\_\_\_ Resting D2 Score \_\_\_\_\_

#### HBAM Condition

HBAM Heart Rate \_\_\_\_\_ HBAM D2 Score \_\_\_\_\_

HBAM D2 Score – Resting D2 Score \_\_\_\_\_

#### Kinect Condition

Kinect Heart Rate \_\_\_\_\_ Kinect D2 Score \_\_\_\_\_

Kinect D2 Score – Resting D2 Score \_\_\_\_\_

#### Mouse Condition

Mouse Heart Rate \_\_\_\_\_ Mouse D2 Score \_\_\_\_\_

Mouse D2 Score – Resting D2 Score \_\_\_\_\_

## 8.4 POST CONDITION SURVEY STUDY 3

Name: \_\_\_\_\_

After doing physical activity, we want you to rate your perception of exertion. This feeling should reflect how heavy and strenuous the exercise feels to you, combining all sensations and feelings of physical stress, effort, and fatigue. Do not concern yourself with any one factor such as leg pain or shortness of breath, but try to focus on your total feeling of exertion. The rating scale ranges from 6 to 20. Choose the number from below that best describes your level of exertion. 9 correspond to "very light" exercise. For a healthy person, it is like walking slowly at his or her own pace for some minutes. 13 on the scale is "somewhat hard" exercise, but it still feels OK to continue. 17 "very hard" is very strenuous. A healthy person can still go on, but he or she really has to push him- or herself. It feels very heavy, and the person is very tired. 20 on the scale is an extremely strenuous exercise level. For most people this is the most strenuous exercise they have ever experienced.

**Circle one of the following numbers:**

6 No exertion at all

7

Extremely light (7.5)

8

9 Very light

10

11 Lights

12

13 Somewhat hard

14

15 Hard (heavy)

16

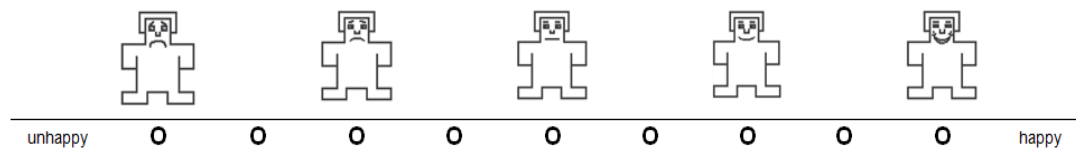
17 Very hard

18

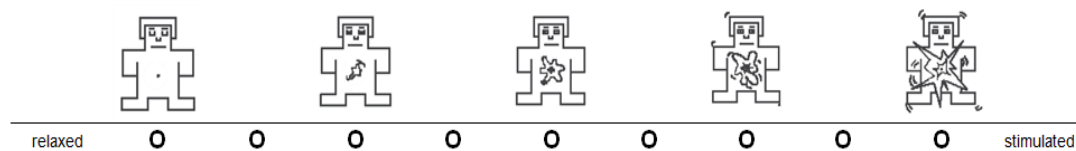
19 Extremely hard

20 Maximal exertion

1. Using the scale presented below, the five graphic figures represent feelings from *unhappy* to *happy*. Please select any of the figures or between any of the figures to express your current feeling.



2. Using the scale presented below, the five graphic figures represent feelings from *relaxed* to *stimulated*. Please select any of the figures or between any of the figures to express your current feeling.



3. Using the scale presented below, please indicate how much you agree with the following statement:

*The game was easy to learn.*

Completely disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Completely agree
---------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	------------------

*The game was fun to play.*

Completely disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Completely agree
---------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	------------------

*The game was exciting to play.*

Completely disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Completely agree
---------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	------------------

*The game was challenging to play.*

Completely disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Completely agree
---------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	------------------

*The game was frustrating to play.*

Completely disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Completely agree
---------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	------------------

*I would consider playing this game when I had 10-minute of free time in a day, such as breaks between classes or lunch breaks*






Completely disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Completely agree
---------------------	-----------------------	-----------------------	-----------------------	-----------------------	-----------------------	------------------

## 8.5 POST EXPERIMENT SURVEY STUDY 3






1. Please circle how much you agree with each statement (Circle one):

Healthy bodies make active minds	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I can concentrate better if I exercise regularly	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I concentrate best in the morning	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I concentrate best in the afternoon	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I concentrate best in the evening	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I can concentrate better shortly after I exercise	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Playing an exercise game can help me to improve my concentration	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Regular exercise will not help improve my concentration	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I do not concentrate better shortly after I exercise	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Playing an exercise game will not help me to improve my concentration	Strongly agree	Agree	Neutral	Disagree	Strongly disagree

2. Using the scale presented below, the five graphic figures represent feelings from *unhappy* to *happy*. Please select any of the figures or between any of the figures to express your current feeling.

									
unhappy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	happy

3. Using the scale presented below, the five graphic figures represent feelings from *relaxed* to *stimulated*. Please select any of the figures or between any of the figures to express your current feeling.

									
relaxed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	stimulated

## 8.6 FIVE-MONTH POST EXPERIMENT SURVEY STUDY 3

Name: \_\_\_\_\_

1. Please circle how much you agree with each statement (Circle one):

Healthy bodies make active minds	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I can concentrate better if I exercise regularly	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I concentrate best in the morning	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I concentrate best in the afternoon	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I concentrate best in the evening	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I can concentrate better shortly after I exercise	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Playing an exercise game can help me to improve my concentration	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Regular exercise will not help improve my concentration	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
I do not concentrate better shortly after I exercise	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Playing an exercise game will not help me to improve my concentration	Strongly agree	Agree	Neutral	Disagree	Strongly disagree



## 8.7 SIX-MONTH POST EXPERIMENT EXPLANATION SURVEY STUDY 3

Name: \_\_\_\_\_

1. Please circle how much you agree with each statement (Circle one) and then explain your answer:

I can concentrate better if I exercise regularly	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Please explain your answer:					
I can concentrate better shortly after I exercise	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Please explain your answer:					
Playing an exercise game can help me to improve my concentration	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Please explain your answer:					

## 8.8 TEACHER'S SURVEY STUDY 3

### Demographic Information

Gender \*

- ☐ Male
- ☐ Female

Which grades have you taught in the past 5 years? \*

Which grades are you currently teaching? \*

### Student Physical Behaviour

How active are your students on a general level? \*

1   2   3   4   5

not active ☐ ☐ ☐ ☐ ☐ very active

How active are students during recess times? \*

1   2   3   4   5

not active ☐ ☐ ☐ ☐ ☐ very active

How active are students during class breaks? \*

1   2   3   4   5

not active ☐ ☐ ☐ ☐ ☐ very active

Do you notice changes in your students' physical activity as they get older? \*

- ☐ Yes
- ☐ No

### Student Physical Behaviour

What changes in physical activity do you notice as the students get older? \*



Page 3

### Student Physical Behaviour

Do you think older students are more sedentary than younger students? \*

- ☐ Yes
- ☐ No

Page 4

### Student Physical Behaviour

Why do you think older students are more sedentary than younger students? \*



Page 5

### Benefits of Activity

Do you notice any effects of physical activity on your students (e.g., when you teach them after PE)? \*

If yes, please describe.



Do you integrate physical activity into classroom activities? \*(Not including PE class)

- ☐ Yes

- ☐ No
- Page 6

## Benefits of Activity

What classroom physical activities do you introduce? \*

What are your students' reactions toward the classroom physical activities that you integrate? \*

Page 7

## Exergames

Would you like to integrate exergames (interactive exercise games) in the classroom? \*

Exergame is a term used for video games that are also a form of exercise

- ☐ Yes
  - ☐ No
- Page 8

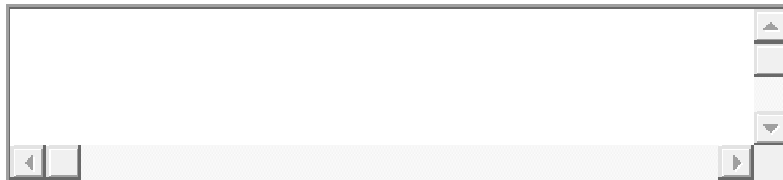
## Exergames

What benefits do you expect? \*

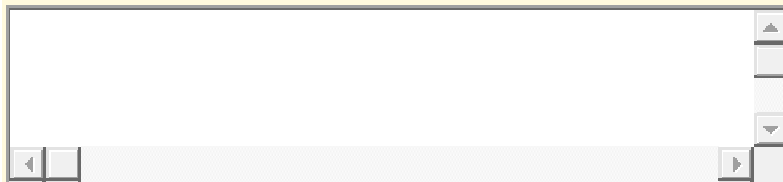
Do you see any potential drawbacks? \*

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**How would you go about integrating exergames? \***

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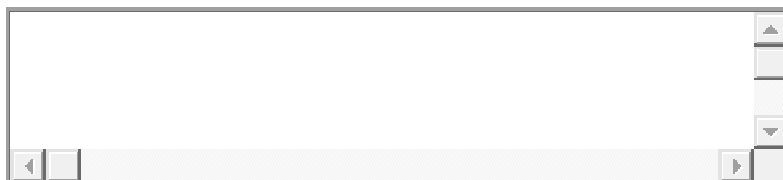
**What advantages might interactive exercise games provide compared to regular exercise? \***

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## Comments

Please add any other comments that you may have.

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